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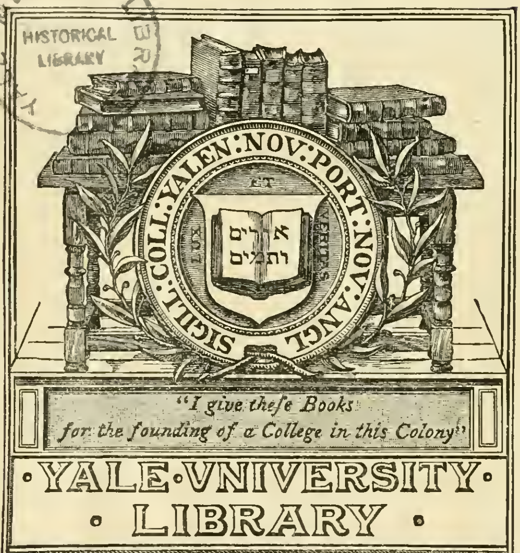

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SEPTEMBER

A MANUAL

OF

PRACTICAL HYGIENE

BY

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SIXTH EDITION

WITH AN APPENDIX

GIVING THE AMERICAN PRACTICE IN MATTERS RELATING TO HYGIENE

PREPARED BY AND UNDER THE SUPERVISION OF

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CIVIL AND SANITARY ENGINEER

VOLUME I.

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PREFACE TO THE SIXTH EDITION.

In presenting the Sixth Edition of the "Manual of Practical Hygiene," I have endeavored to keep within much the same limits as in the previous edition, by omitting matter which had either become out of date or was no longer necessary. In this way space has been obtained for matter which the progress of science and the results of experience rendered it desirable to add. Some slight changes have been made, such as putting all the directions for making chemical solutions in one appendix at the end of Volume II., and uniting all the questions of disinfection and deodorization in one chapter. The prefaces to former editions have been omitted, as being no longer required. The index is as full as on the last occasion.

F. de CHAUMONT.

Woolston Lawn,
Southampton, *March*, 1883.

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INTRODUCTION.

Hygiene is the art of preserving health; that is, of obtaining the most perfect action of body and mind during as long a period as is consistent with the laws of life. In other words, it aims at rendering growth more perfect, decay less rapid, life more vigorous, death more remote.

This art has been practised from the earliest times. Before Hippocrates there were treatises on hygiene, which that great master evidently embodied in his incomparable works. It was then based on what we should now call empirical rules—viz., simply on observations of what seemed good or bad for health. Very early, indeed, the effects of diet and of exercise were carefully noticed, and were considered the basis of hygiene.[1] Hippocrates, indeed, appears to have had a clear conception of the relation between the amount of food taken and of the mechanical energy produced by it; at least, he is extremely careful in pointing out that there must be an exact balance between food and exercise, and that disease results from excess either way.

The effects on health of different kinds of air, of water, and to some extent of soils, were also considered at a very early date; though naturally the ignorance of chemistry prevented any great advance in this direction. Hippocrates summed up the existing knowledge of his time on the six articles, which in after-days received the absurd name

[1] Herodicus, one of the preceptors of Hippocrates, was the first to introduce medicinal gymnastics for the improvement of health and the cure of disease; though gymnastics in training for war had been used long before. Plutarch says of him, that laboring under a decay which he knew could not be perfectly cured, he was the first who blended the gymnastic art with physic, in such a manner as protected to old age his own life, and the lives of others afflicted with the same disease. He was censured by Plato for keeping alive persons with crazy constitutions.—Mackenzie on Health.

of the "Non-naturals."[1] The six articles, whose regulation was considered indispensably necessary to the life of man, were—air, aliment, exercise and rest, sleep and wakefulness, repletion and evacuation, the passions and affections of the mind.

With the exception of the attempts of the alchemists, and of the chemical physicians, to discover some agent or drug which might increase or strengthen the principle of life,[2] the practice of hygiene remained within the same limits until physiology (the knowledge of the laws of life) began to be studied. Hygiene then began to acquire a scientific basis. Still retaining its empirical foundation drawn from observation, it has now commenced to apply the discoveries of physi-

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[1] This title originated in a sentence of Galen, and was introduced into use by the jargon of the Peripatetic school. It was employed in all treatises on hygiene for probably nearly 1,500 years.

[2] It was when chemistry was being rudely studied by the alchemists that an entirely different school of hygiene arose. The discovery of chemical agents, and the great effect they produce on the body, led to the notion that they could in some way aid the forces of life, and insure a prolonged, if not an eternal youth, and a life of ages instead of one of years. This belief, the natural result of the discovery of new powers, has not yet entirely died out; and while there are some who still look to every fresh agent as possibly containing "the balsam of life," there are also still enthusiasts who search the mystic tomes of the alchemists or the Rosicrucians, in the faith that, after all, the great secret was really found. It may be worth while to consider the idea which underlaid the dreams of the alchemists. Life was looked on as an entity or principle liable to constant waste, and to eventual expenditure. If some agent could be found to arrest the waste, to crystallize, as it were, the tissues in their full growth and vigor, decay, it was conceived, would be impossible, and youth would be eternal. In other cases, it was supposed that the agent would itself contain the principle of life, and therefore would at once restore destroyed health, and recall again departed youth. We now know this idea to be wrong in every point. The constant decay the alchemists sought to check is life itself, for life is but incessant change, and what we call decay is only a metamorphosis of energy. To arrest the changes in the body for one single moment would be death, or, short of death, it would be lessening of the energy which is the expression of life. Nor is there any hope that the extension of the period of vital energy can ever be accomplished except by improving the nutrition of the tissues. Here, indeed, it is just possible that, in time to come, drugs will aid Hygiene, either by better preparing food for the purposes of nutrition, or by removing or preventing those chemical changes in the tissues which we call decay. But at present, certainly, no rules can be laid down for the use of drugs in hygiene, except in that debatable land which lies between hygiene and the practice of medicine, that is, in that uncertain region which we do not like to call disease, and yet which is not health.

ology to the improvement of health, and to test the value of its own rules by this new light. It is now gradually becoming an art based on the science of physiology, with whose progress its future is identified.

But the art of hygiene has at present still another object. If we had a perfect knowledge of the laws of life, and could practically apply this knowledge in a perfect system of hygienic rules, disease would be impossible. But at present disease exists in a thousand forms, and the human race languishes, and at times almost perishes, under the grievous yoke. The study of the causes of disease is strictly a part of physiology,[1] but it can only be carried out by the practical physician, since an accurate identification of the diseases is the first necessary step in the investigation of causes.

The causes being investigated, the art of hygiene then comes in to form rules which may prevent the causes or render the frame more fitted to bear them ; and as in the former case it was the exponent of physiology, in this case it becomes the servant of the pathologist.

Taking the word hygiene in the largest sense, it signifies rules for perfect culture of mind and body. It is impossible to dissociate the two. The body is affected by every mental and moral action ; the mind is profoundly influenced by bodily conditions. For a perfect system of hygiene we must train the body, the intellect, and the moral faculties in a perfect and balanced order.

But is such a system possible ?

Is there, or will there ever be, such an art, or is the belief that there will be, one of those dreams which breathe a blind hope into us, a hope born only of our longings, and destined to die of our experience ? And, indeed, when we look around us and consider the condition of the world—the abundance of life, its appalling waste ; the wonderful contrivances of the animal kingdom, the apparent indifference with which they are trampled under foot ; the gift of mind, its awful perversion and alienations ; and when, especially, we note the

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[1] Physiology and pathology are, in fact, one ; normal and abnormal life, regular and irregular growth and decay, must be studied together, just as, in fact, human physiology is imperfect without the study of all the other forms of life, animal and vegetable, which are in the world. Separated for convenience, these various studies will finally converge.

condition of the human race, and consider what it apparently might be, and what it is; its marvellous endowments and lofty powers; its terrible sufferings and abasement; its capacity for happiness, and its cup of sorrow; the boon of glowing health, and the thousand diseases and painful deaths,—he must indeed be gifted with sublime endurance or undying faith who can still believe that out of this chaos order can come, or out of this suffering happiness and health.

Whether the world is ever to see such a consummation no man can say; but as ages roll on, hope does in some measure grow. In the midst of all our weaknesses, and all our many errors, we are certainly gaining knowledge, and that knowledge tells us, in no doubtful terms, that the fate of man is in his own hands.

It is undoubtedly true that we can, even now, literally choose between health or disease; not, perhaps, always individually, for the sins of our fathers may be visited upon us, or the customs of our life and the chains of our civilization and social customs may gall us, or even our fellow-men may deny us health, or the knowledge which leads to health. But as a race, man holds his own destiny, and can choose between good and evil; and as time unrolls the scheme of the world, it is not too much to hope that the choice will be for good.

Looking only to the part of hygiene which concerns the physician, a perfect system of rules of health would be best arranged in an orderly series of this kind.

The rules would commence with the regulation of the mother's health while bearing her child, so that the growth of the new being should be as perfect as possible. Then, after birth, the rules (different for each sex at certain times) would embrace three epochs;[1] of growth (including infancy and youth); of maturity, when for many years the body remains apparently stationary; or decay, when, without actual disease, though, doubtless, in consequence of some chemical changes, molecular feebleness and death commence in some part or other, forerunning general decay and death.

In these several epochs of his life, the human being would have to be considered—

[1] First expressly noted by Galen.

1st, In relation to the natural conditions which surround him, and which are essential for life, such as the air he breathes; the water he drinks; his food, the source of all bodily and mental acts; the soil which he moves on, and the sun which warms and lights him, etc.; in fact, in relation to nature at large.

2d, In his social and corporate relations, as a member of a community with certain customs, trades, conditions of dwellings, clothing, etc.; subjected to social and political influences, sexual relations, etc.

3d, In his capacity as an independent being, having within himself sources of action, in thoughts, feelings, desires, personal habits, all of which affect health, and which require self-regulation and control.

Even now, incomplete as hygiene necessarily is, such a work would, if followed, almost change the face of the world. But would it be followed?

In some cases the rules of hygiene could not be followed, however much the individual might desire to do so. For example, pure air is a necessity for health; but an individual may have little control over the air which surrounds him, and which he must draw into his lungs. He may be powerless to prevent other persons from contaminating his air, and thereby striking at the very foundation of his health and happiness. Here, as in so many other cases which demand regulation of the conduct of the individuals toward each other, the State steps in for the protection of its citizens, and enacts rules which shall be binding upon all. Hence arises what is now termed "State Medicine," a matter of the greatest importance. The fact of "State Medicine" being possible, marks an epoch in which some sanitary rules receive a general consent, and indicates an advancing civilization. Fear has been expressed lest State Medicine should press too much on the individual, and should too much lessen the freedom of personal action. This, however, is not likely, as long as the State acts cautiously, and only on well-assured scientific grounds, and as long as an unshackled Press discusses with freedom every step.[1]

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[1] A watchful care over the health of the people, and a due regulation of matters which concern their health, is certainly one of the most important functions of Government. The fact that, in modern times, the subject of hygiene generally, and State Medicine in particular, has commenced to attract so much the public attention, is un-

There are, however, some cases in which the State cannot easily interfere, though the individual may be placed under unfavorable hygienic conditions by the action of others. For example, in many trades, the employed are subjected to danger from the carelessness, or avarice, or ignorance of the employers. Every year the State is, however, very properly more and more interposing and shielding the workman against the dangers which an ignorant or careless master brings on him.

But in other cases the State can hardly interpose with effect; and the growth of sanitary knowledge, and the pressure of public opinion, alone can work a cure, as, for example, in the case of the dwellings of our poorer classes. In many parts of the country the cottages are

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doubtedly owing to the application of statistics to public health. It is impossible for any nation, or for any Government, to remain indifferent when, in figures which admit of no denial, the national amount of health and happiness, or disease and suffering, is determined. The early Statistical Reports of the Army by Tulloch, Marshall, and Balfour, directed attention to the importance of this matter. The establishment of the Registrar-General's office in 1838, and the commencement of the system of accurately recording births and deaths, will hereafter be found to be, as far as the happiness of the people is concerned, one of the most important events of our time. We owe a nation's gratitude especially to him to whose sagacity the chief fruits of the inquiry are due, to William Farr.

Another action of the Government in our day was scarcely less important. It is impossible to overrate the value of the Government Inquiry into the Health of Towns, and of the country generally, which was commenced forty years ago by Edwin Chadwick, Southwood Smith, Neil Arnott, Sutherland, Guy, Toynbee, and others, and has, in fact, been continued ever since by the official successors of these pioneers, the former medical officer to the Privy Council, Mr. Simon, the late Dr. Seaton, and the present medical officer of the Local Government Board, Dr. Buchanan. Consequent on this movement came the appointment of medical officers of health to the different towns and parishes. The reports published by many of these gentlemen have greatly advanced the subject, and have done much to diffuse a knowledge of hygiene among the people, and at the same time to extend and render precise our knowledge of the conditions of national health. When the effect of all these researches and measures develops itself, it will be seen that even great wars and political earthquakes are really nothing in comparison with these silent social changes. Even now legislation, such as the Public Health Act, 1875, and the various measures since passed, is beginning to exert a deep influence. Legislation, and action based on legislation, can only proceed slowly, and we must be satisfied if there be a continual advance, though it may not be so rapid as some desire.

unfit for human beings; in many of our towns, the cupidity of builders runs up houses of the most miserable structure, for which there is unhappily no lack of applicants; or masters oblige their men to work in rooms, or to follow plans which are most detrimental to health.

But even in such cases it will be always found that self-interest would really indicate that the best course is that we should do for our neighbors as for ourselves. Analyze also the effect of such selfishness and carelessness as has been referred to on the nation at large, and we shall find that the partial gain to the individual is far more than counterbalanced by the injury to the State, by the discontent, recklessness, and indifference produced in the persons who suffer, and which may have a disastrous national result. It is but too commonly forgotten that the whole nation is interested in the proper treatment of every one of its members, and in its own interest has a right to see that the relations between individuals are not such as in any way to injure the well-being of the community at large.

In many cases, again, the employer of labor finds that, by proper sanitary care of his men, he reaps at once an advantage in better and more zealous work, in fewer interruptions from ill-health, etc., so that his apparent outlay is more than compensated.

This is shown in the strongest light by the army. The State employs a large number of men, whom it places under its own social and sanitary conditions. It removes from them much of the self-control with regard to hygienic rules which other men possess, and is therefore bound by every principle of honest and fair contract to see that these men are in no way injured by its system. But more than this: it is as much bound by its self-interest. It has been proved over and over again that nothing is so costly in all ways as disease, and that nothing is so remunerative as the outlay which augments health, and in doing so, augments the amount and value of the work done.

It was the moral argument as well as the financial one which led Lord Herbert to devote his life to the task of doing justice to the soldier, of increasing the amount of his health, and moral and mental training, and, in so doing, of augmenting not only his happiness, but the value of his services to the country.

PRACTICAL HYGIENE.

Book I.

CHAPTER I.

WATER.

The supply of wholesome water in sufficient quantity is a fundamental sanitary necessity. Without it injury to health inevitably arises, either simply from deficiency of quantity, or more frequently from the presence of impurities. In all sanitary investigations, the question of the water supply is one of the first points of inquiry, and of late years quite unexpected evidence has been obtained of the frequency with which diseases are introduced by the agency of water. In such an investigation, if the headings of the sub-sections of this chapter are followed, and the facts are noted under each heading in order, it will be hardly possible to overlook any condition which may have affected health. The order of investigation would be as follows :—Quantity of water per head ; how is it collected ; stored ; distributed ; what is its composition ; is it wholesome water at its source and throughout, or has it been contaminated at any point of its distribution ; what are the effects presumed to arise from it ? [1]

[1] *Army Regulations on the Subject of Water.*—The Regulations for the Medical Department of Her Majesty's Army frequently refer to the supply of water. In Part I., Section iii., paragraph 21 (*c*), the Surgeon-General and Deputy Surgeons-General are directed to "ascertain that the water-supply is good and abundant, and perfectly protected from pollution." Also paragraph 21 (*b*), "that the means of ablution and cleanliness are sufficient, and made use of by the men." As regards hospitals they are also to ascertain (paragraph 25), "that the water-supply is pure, and abundant and sufficient for all the requirements of a hospital, . . . and that the lavatories, bath-rooms, and water-closets are kept in proper order." In the Sanitary Regulations, Part V., Section ii., paragraph 618, the medical officer in charge of troops is ordered to examine, from time to time, "the quality and amount of drinking-water," and to ascertain that there is "no soakage from latrines, cesspools, drains, or other sources of impurity." He is also ordered to inspect the lavatories and baths. In Sections vi. and vii. the same supervision over the water-supply of camps and garrisons and transport ships is enjoined.

When an army takes the field a Sanitary Officer is appointed, and he examines into all sanitary points, including the water-supply. (Section viii., paragraph 679.)

In the quarterly and annual reports the water-supply has to be considered, in

SECTION I.

ON THE QUANTITY AND SUPPLY OF WATER.

Sub-Section I.—1. Quantity of Water for Healthy Men.

In estimating the quantity of water required daily for each person, it is necessary to allow a liberal supply. There should be economy and avoidance of waste ; but still, any error in supply had far better be on the side of excess. In England many poor families, either from the difficulty of obtaining water, or of getting rid of it, or from the habits of uncleanliness thus handed down from father to son, use an extremely small amount. It would be quite incorrect to take this amount as the standard for the community at large, or even to fix the smallest quantity which will just suffice for moderate cleanliness. It is almost impossible to give a definition of cleanliness, nor perhaps is it necessary, since there is a general understanding of what is meant.

It must be clearly understood for what purposes water is supplied. It may be required for drinking, cooking, and ablution of persons, clothes, utensils, and houses ; for cleansing of closets, sewers, and streets ; for the drinking and washing of animals, washing of carriages and stables ; for trade purposes ; for extinguishing fires ; for public fountains or baths, etc.

In towns supplied by water companies, the usual mode of reckoning is to divide the total daily supply in gallons by the total population, and to express the amount per head per diem.

The following are some of the gross amounts used at the present time for all the above purposes, as judged of in this way :—

	Gallons per head of population daily.
New River Company in London, 1879[1]	28.7
East London Water-Work Company, 1879	34.2
Kent " " "	29.1
Chelsea " " "	36.5
West Middlesex " " "	26.5
Grand Junction " " "	32.9
Southwark and Vauxhall " "	40.9
Lambeth " "	31.5
Average of London Districts	32.7

common with other sanitary conditions, including "the sources, quality, and quantity of the water-supply, and whether it is wholesome, and what means of purification are in use, if such be necessary. Also, "Baths and lavatories, their conditions, and if sufficient for cleanliness for troops and sick ; whether there are bathing parades, and how often a week." (Appendix No. 15.)

In the Instructions in Case of an Invasion of Cholera (Appendix No. 14, paragraph 7), special attention is directed to the water-supply. Provision is also made for the chemical examination of water when required, Part V., Section vi., paragraph 667.

[1] These and other London amounts are taken from the Report of the Select Committee of the House of Commons on London Water-Supply, 1880, p. 303. With the exception of the three first on the list the London supply is from the Thames. The Edinburgh amount is taken from the same work.

	Gallons per head of population daily.
Southampton Water-Work Company, 1879	35
Glasgow Water-Work Company, 1879	50
Edinburgh	35
Liverpool	30 [1]
Sheffield	20
Paris	31
Calcutta (for Europeans),[2] amount originally intended	30 ?
" (for Natives), amount originally intended	15 ?
New York[3]	83

In 1857 the average supply to fourteen English towns, of second-rate magnitude, was 24 gallons. The average of 72 English and Scotch towns, supplied on the constant system, is 134.4 gallons per house (but this includes the supply to factories, of which there were 16,087 to 889,028 houses), or (at 5 persons to each house), 26.7 per head; of 23 towns, supplied on the intermittent system, 127 per house, 25.4 head, including 1,367 factories to 137,414 houses; and of London, also on the intermittent system, 204, or 41 per head, including 5,340 factories to 499,582 houses.[4] The range in individual cases is, however, very great, from 25 gallons per house (5 per head) in one small town to 700 at Middlesborough (140 per head). Mr. Bateman states that in the manufacturing towns of Lancashire and Yorkshire, the present amount is from 16 to 21 gallons; in some cases less.[5]

At Norwich about 14½ gallons daily per head are supplied on the constant system, of which 10.5 are taken for domestic purposes, 3 for trade, and .7 gallons for public and sanitary purposes.[6] In Manchester the supply is also constant, and is 14 gallons per head for domestic, and 7 for trade purposes. In 1878 in fifteen American cities the supply was on the average 55 gallons per head.[7]

By decision of the Secretary of State for War, a soldier receives 15 gallons daily; no extra allowance is made for the wives and children in a regiment.

The gross amount thus taken is used for different purposes, which must be now considered.

Amount for Domestic Purposes, excluding Water-Closets.

This item includes drinking, cooking, washing the person, the clothes, the house utensils, and the house.

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[1] See page 15.

[2] The daily supply in Calcutta was, in 1871, 5,000,000 gallons of filtered water; in 1879 it was 7¼ millions and 1,000,000 gallons unfiltered for watering roads. This, however, after all deductions, only left 3 gallons per head for domestic purposes. A new scheme is in progress, which will provide 8,000,000 more daily, thus securing 12 gallons per head.

[3] In former editions this was stated at 300, but it is given as 100 (?) in Buck's Hygiene and Public Health. These are, however, U. S. gallons, equal to 83 imperial gallons.

[4] Sixth Report of the Rivers Pollution Commissioners, pp. 232, 233.

[5] See table in the Sixth Report of the Rivers Pollution Commissioners.

[6] Report by Dr. Pole, F.R.S. Enormous saving was accomplished by taking steps to prevent waste.

[7] Dr. F. H. Brown, in Buck's Hygiene, vol. i., p. 180. A table is also given by Prof. W. R. Nichols (p. 212) showing the supply to eighteen cities, ranging from 20 imperial gallons in Louisville to 116 in Washington.

An adult requires daily about 70 to 100 ounces ($3\frac{1}{2}$ to 5 pints) of water for nutrition ; but about 20 to 30 ounces of this are contained in the bread, meat, etc., of his food, and the remainder is taken in some form of liquid. There are, however, wide ranges from the average. Women drink rather less than men ; children drink, of course, absolutely less, but more in proportion to their bulk than adults. The rules for transport vessels allow 8 pints in, and 6 out of the tropics for cooking and drinking. During hot weather and great exertion a man will, of course, drink much more.

In some experiments made for the War Office in 1866, at the Richmond Barracks in Dublin and the Anglesea Barracks in Portsmouth, the amount of the different items of the domestic supply (excluding latrines, which take 5 gallons per head) is thus given :—

	Gallons per soldier daily.
Cook-house	1
Ablution rooms and baths	4
Cleaning barracks	2.25
Wash-house and married people	2.5
	9.75

Dr. Parkes measured the water expended in several cases ; the following was the amount used by a man in the middle class, who may be taken as a fair type of a cleanly man belonging to a fairly clean household :—

	Gallons daily per one person.
Cooking	.75
Fluids as drink (water, tea, coffee)	.33
Ablution, including a daily sponge-bath, which took $2\frac{1}{2}$ to 3 galls.	5
Share of utensil and house-washing	3
Share of clothes (laundry) washing estimated	3
	12

These results are tolerably accordant with the Dublin experiments, if we remember that with a large household there is economy of water in washing utensils and clothes, and that the number of wives and children in a regiment is not great. In poor families, who draw water from wells, the amount has been found to vary from 2 to 4 gallons per head, but then there was certainly not perfect cleanliness.

Mr. Bateman [1] states that in a group of cottages with 82 inmates, the daily average amount was $7\frac{1}{2}$ gallons per head, and in another group 5 gallons per head. Dr. Letheby found in the poor houses in the city of London the amount to be 5 gallons.[2] In experiments in model lodging-houses, Mr. Muir states that 7 gallons daily were used.[3] Mr. Easton, in his own house in London, found he used about 12 gallons per head, of which about 5 were for closets, leaving 7 for other uses ; but probably the laundry washing was not included. In the convict prison at Portsmouth, where there are water-closets, and each prisoner has a general bath once a week, the amount is 11 gallons (Wilson).

[1] On Constant Water Supply, by Messrs Bateman, Beggs, and Rendle. 1867.

[2] Report of the East London Water Bill Committee, 1867. Questions 2346 and 2347.

[3] Ibid., p. 5.

In several of the instances just referred to, it may be questioned whether the amount of cleanliness was equal to what would be expected in the higher ranks. In most instances quoted no general baths were used; but it is now becoming so common in England to have bath-rooms, that it is said they are often put even in eight-roomed houses. A general bath for an adult requires, with the smallest adult bath (*i.e.*, only 4 feet long and 1 foot 9 inches wide), 38 gallons, and many baths will contain 50 to 60 gallons. A good shower-bath will deliver 3 to 6 gallons. General baths used only once a week will add 5 or 6 gallons per head to the daily consumption.

We may safely estimate that for personal and domestic use, without baths, 12 gallons per head daily should be given as a usual minimum supply; and with baths and perfect cleanliness, 16 gallons should be allowed. This makes no allowance for water-closets or for unavoidable waste. If from want of supply the amount of water must be limited, 4 gallons daily per head for adults is probably the least amount which ought to be used, and in this case there could not be daily washing of the whole body, and there must be insufficient change of underclothing.

If public baths are used the amount must be greatly increased. The largest baths the world has seen, those of Ancient Rome, demanded a supply of water so great as, according to Leslie's calculations, to raise the daily average per head to at least 300 gallons.

Amount for Water-Closets.

The common arrangements with cisterns allow any quantity of water to be poured down, and many engineers consider that the chief waste of water is owing to water-closets. In some districts, by attention to this point, the consumption has been greatly reduced; in one case from 30 to 18, and in another from 20 to 12 gallons per head. It has not yet been precisely determined what quantity should be allowed for water-closets. Small cisterns, termed water-waste preventers, are usually put up in towns with constant water-supply, which give only a certain limited amount each time the closet is used. The usual size now in use holds about two gallons; but even two gallons are often insufficient to keep the pan and soil-pipe perfectly clean. This depends a good deal upon the kind of closet used. The water-waste preventer must be sometimes allowed to fill again, and be again emptied. Considering also that some persons will use the closet twice daily and sometimes oftener, and that occasionally more water must be used for thoroughly flushing the pan and soil-pipe, six gallons a day per head should probably be allowed for closets. In this particular instance a false economy in the use of water is most undesirable. Water latrines require less; the amount is not precisely known; the experiments of the Royal Engineers at Dublin give an average of five gallons per head, but it is considered this might be reduced.

In fixing the above quantities, viz., 12 gallons per head for all domestic purposes except general baths and closets, 4 gallons additional for general baths, and 6 for water-closets, endeavors have been made to base them upon facts, and they are probably not much in error. It is, however, necessary to make some allowance for unavoidable waste within the premises, and for extra supply to closets, and it will be a moderate estimate to allow 3 gallons daily per head for this purpose. This will make 25 gallons.

There is another reason for believing that an amount of about 25 gallons per head should pass from every house daily into sewers, if sewers are used.

It is that in most cases this quantity seems necessary to keep the sewers perfectly clear, though in some cases, no doubt, with a well-arranged and constructed sewerage, a less amount may suffice. But the complete clearage of sewers is a matter of such fundamental importance that it is necessary to take the safest course. Hitherto much water has run merely to waste.

Amount for Animals.

From experiments conducted in some cavalry stables in 1866, by the Royal Engineers, the War Office authorities have fixed the daily supply for cavalry horses at 8 gallons, and for artillery horses at 10 gallons per horse. This is to include washing horses and carriages. The amount seems rather small. Of course the amount that horses drink varies as much as in the case of men, and depends on food, weather, and exertion; but if a horse is allowed free access to water at all times, and this should be the case, he will drink on an average 6 to 10 gallons, and at times more. In the month of October, with cool weather, a horse 16 hands high, doing 8 miles a day carriage work, and fed on corn and hay, was found to drink 7½ gallons. Another carriage horse drank nearly the same amount. In a stable of cavalry horses, doing very little work, and at a cool time of the year, the amount per horse was found to be 6⅓ gallons. The amount used for washing was 3 gallons daily. In hot and dirty weather the quantity for both purposes would be larger. For washing a horse requires at least 1½ gallon, and twice this amount if he is washed twice a day. There is a saving, however, if grooms wash several horses in the same water. It is difficult to say how much is used for carriage washing. On the whole, including carriage washing, etc., 16 gallons per horse is not an excessive amount. A cow or an ox, on dry food, will drink 6 or 8 gallons; a sheep or pig, ½ to 1 gallon. In the Abyssinian expedition, the following was the calculation for the daily expenditure of water per head on shipboard:—

	Gallons.
Elephants	25
Camels	10
Oxen (large draught)	6
Oxen (small pack animals)	5
Horses	6
Mules and ponies	5

For 20 elephants and 100 men, 50,000 gallons were put on board for a voyage of 60 days.[1]

Amounts required for Municipal and Trade Purposes.

For municipal purposes water is taken for washing and watering streets, for fountains, for extinguishing fires, etc. The amount for these and for trade purposes will vary greatly. Professor Rankine,[2] who gives an average allowance of 10 gallons per head for domestic purposes, proposes 10 more for trade and town use in non-manufacturing towns, and another 10 gallons in manufacturing towns. Considering, however, the comparatively small number of horses and cows in towns as compared with the human

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[1] This information was derived from Major Holland, Assistant Quartermaster-General, Abyssinian Army.

[2] Civil Engineering, 1862, p. 731.

population, and the frequent rains in this country which lessen watering of streets, the two latter quantities might, perhaps, in most cases be halved.

If, now, the total daily amount for all purposes be stated per head of population, it will be as follows : —

	Gallons.
Domestic supply (without baths or closets)...........	12
Add for general baths..............................	4
Water-closets......................................	6
Unavoidable waste..................................	3[1]
Total house supply.................................	25
Town and trade purposes, animals in non-manufacturing town......................................	5[2]
Add for exceptional manufacturing towns............	5
	35

In India and hot countries generally, the amounts now laid down would have to be altered. Much more must be allowed for bathing and for washing generally, while a fresh demand would arise for water to cool mats, punkahs, or air-passages by evaporation. In Calcutta it was intended to supply to Europeans 30 gallons per head, and to natives 15 gallons daily,[3] but the amount has been really much less up to the present time.

In Madras it was assumed that the ultimate amount used would be 20 gallons per head, including all residents.[4] At present (in 1879) the total supply is about 2½ millions daily; this in a population of about 400,000 would give 6¼ gallons per head. As yet, however, all the population do not use it.

2. Amount Required for Sick Men.

In hospitals a much larger quantity must be provided, as there is so much more washing and bathing. From 40 to 50 gallons per head are often used. There are no good experiments as to the items of the consumption, but the following is probably near the truth :—

	Gallons daily.
For drinking and cooking, washing kitchen and utensils ..	2 to 4
For personal washing and general baths	18 to 20
For laundry washing....................................	5 to 6
Washing hospital, utensils, etc........................	3 to 6
Water-closets	10
	38 to 46

It would be very desirable to have more precise data ; possibly the amount for closets is put too high, but not greatly so when all cases are taken into account.

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[1] Most engineers reckon the waste much higher than this ; there is no doubt much room for economy in this matter. The greatest waste appears to be in transit before reaching the houses.

[2] This allowance will vary in every case, and must be verv uncertain. In the London district 18 per cent. is reckoned for trade purposes.

[3] Gordon's Army Hygiene, p. 426.

[4] Captain Tulloch's Report on the Drainage of Madras, 1865, p. 93.

Sub-Section II.—Collection, Storage, and Distribution of Water.

The daily necessary quantity of water per head being determined, the next points are to collect, store, and distribute it.

1. Collection.

In many cases collections of water occur naturally in the depressions of the surface, or the commingling of small streams forms rivers. The collection by men consists almost entirely in imitating these natural processes, and in directing to, and finally arresting at some point, the rain or the streamlets formed by the rain. The arrangements necessarily differ in each case. Rain-water is collected from roofs, or occasionally from pavements and flags, or cemented ground; in hilly countries, with deep ravines, a reservoir is sometimes formed by carrying a wall across a valley, which is well placed for receiving the tributary waters of the adjacent hills, or on a flatter surface trenches may be arranged, leading finally to an excavated tank.

The collection of the surface water which has not penetrated is usually aimed at, but it has been proposed by Mr. Bailey-Denton [1] to collect the sub-soil water by drainage-pipes, and thus to accomplish two objects—to dry the land, and to use the water taken out of it. Below the surface the water is collected by wells, shallow, deep, and Artesian, or by boring.

With respect to wells, if they are situated near a river, and do not produce sufficient water, it has been recommended to lay perforated earthenware pipes parallel to the river, and below its fine-weather level, in trenches not less than six feet deep, and filled up above the pipes with fine gravel. The pipes end in the well, and water passing from the river and filtered through the gravel passes into them. The American tube-well (Norton's patent) is a very useful invention. It is merely a small iron pipe driven into the ground in lengths by means of a "monkey"; the water passes through small holes in the lowest part of the pipe, and is drawn up by a common or double-action pump according to the depth.[2]

All these matters fall within the province of the engineer, and the medical part of the question is chiefly restricted to the consideration of the purity of the water. The cleanliness and nature of the surface (lead, zinc, copper, etc.) on which rain falls; the kind of ground; and of cultivation; the amount of manuring; the nature of the subsoil if drainage water is used, and points of the like kind, have to be considered and supplemented by a chemical examination.

Rain.—The *amount* of water given by rain can be easily calculated, if two points are known, viz., the amount of rainfall, and the area of the receiving surface. The rainfall can only be determined by a rain-gauge (the mode of constructing which is given in the chapter on Practical Meteorology); the area of the receiving surface must be measured.

Supposing that it be known that the rainfall amounts to twenty-four inches per annum, and the area of the receiving surface (say the roof of a house) is five hundred square feet:

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[1] On the Supply of Water to Villages and Farms, by Mr. Bailey-Denton, C.E.

[2] In the Ashantee Expedition the tube-well did not succeed, as it got clogged with sand. See Sir A. D. Home's Report, Army Medical Reports, vol. xv., p. 247.

Multiply the area by 144 (number of square inches in one square foot), to bring it into square inches, and multiply this by the rainfall. The product gives the number of cubic inches of rain which fall on the house-top in a year, or in any time the rainfall of which is known. This number, if divided by 277.274, or multiplied by .003607, will give the number of gallons which the roof of the house will receive in a year (viz., in this case 6,232 gallons); or, if it is wished to express it in cubic feet, the number of cubic inches must be divided by 1728 (number of cubic inches in a cubic foot), or multiplied by .00058.

To calculate the receiving surface of the roof of a house, we must not take into account the slope of the roof, but merely ascertain the area of the flat space actually covered by the roof. The joint areas of the ground-floor rooms will be something less than the area of the roof, which also covers the thickness of the walls and the eaves.

In most English towns the amount of roof space for each person cannot be estimated higher than 60 square feet, and in some poor districts is much less. Taking the rainfall in all England at 30 inches, and assuming that all is saved, and that there is no loss from evaporation, the receiving surface for each person would give 935 gallons, or $2\frac{1}{2}$ gallons a day. But as few town houses have any reservoirs, this quantity runs in great part to waste in urban districts. In the country it is an important source of supply, being stored in cisterns or water-butts. If, instead of the roof of a house, the receiving surface be a piece of land, the amount may be calculated in the same way. It must be understood, however, that this is the total amount reaching the ground; all of this will not be available; some will sink into the ground, and some will evaporate; the quantity lost in this way will vary with the soil and the season from the one-half to seven-eighths. To facilitate these calculations, tables have been constructed by engineers.[1]

One inch of rain delivers 4.673 gallons on every square yard, or 22,617 gallons (101 tons by weight) on each square acre.[2]

In estimating the annual yield of water from rainfall, and the yield at any one time, we ought to know the greatest annual rainfall, the least, the average, the period of the year when it falls, and the length of the rainless season. It must also be remembered that the amount of rainfall differs very greatly even in places near together.

Springs, Rivers.—It will often be a matter of great importance to determine the yield of springs and small rivers, as a body of men may have to be placed for some time in a particular spot, and no engineering opinion, perhaps, can be obtained.

A spring is measured most easily by receiving the water into a vessel of known capacity, and timing the rate of filling. The spring should be opened up if necessary, and the vessel should be of large size. The vessel may be measured either by filling it first by means of a known (pint or gallon) measure, or by gauging it. If it be round or square, its capacity can be at once known by measuring it, and using the rules laid down in the chapter for measuring the cubic amount of air in rooms. The capacity of the vessel in cubic feet may be brought into gallons if desirable, by multiplying by 6.23. If a tub or cask only be procurable, and if there is no pint or gallon measure at hand, the following rule may be useful:—

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[1] Beardmore's Manual of Hydrology, p. 61; see also table in Appendix E, Vol. II.

[2] To bring cubic inches into gallons, multiply by 40 and divide by 11,091, or multiply at once by .003607.

Take the bung diameter in inches, by measuring the circumference at the bung, dividing by 3.1416, and making an allowance for the thickness of the staves; square the bung diameter, and multiply by 39. Take the head diameter in inches by direct measurement, and square it, and multiply by 25. Multiply one diameter by the other, and the product by 26. Add the sums, and multiply by the length of the cask in inches; then multiply by .000031473, and the result is given in gallons.[1]

When it is required to ascertain the yield of any small watercourse with some nicety, it is the practice of engineers to dam up the whole stream, and convey the water by some artificial channel of known dimensions.

1. A wooden trough of a certain length, in which the depth of water and the time which a float takes to pass from one end to the other is measured.

2. A sluice of known size, in which the difference of level of the water above and below the sluice is measured.[2]

3. A weir formed by a plank set on edge, in which a rectangular notch is cut, usually one foot in width; over this the water flows in a thin sheet, and the difference of level is measured by the depth of the water as it flows over the notch. Then by means of a table the amount of water delivered per minute is read off. The weir must be formed of very thin board and be perfectly level; a plumb-line has generally to be used.[3] This plan of measuring the yield of water-courses is the one now most generally adopted by engineers.

The same object may, however, be attained with sufficient accuracy for the purposes of the medical officer by selecting a portion of the stream where the channel is pretty uniform, for the length of, say not less than twelve or fifteen yards, and in the course of which there are no eddies. Take the breadth and the average depth in three or four places, to obtain the sectional area. Then, dropping in a chip of wood, or other light object, notice how long it takes to float a certain distance over the portion of channel chosen. From this can be got the surface velocity per second, which is greater of course than the bottom or the mean velocity. Take

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[1] Nesbit's Practical Mensuration, 1859, p. 309. Another rule, applicable to common forms of casks, is to multiply the cube of the diagonal by 0.0025; the cube of the diagonal is got by adding the square of half the sum of the diameters in inches to the square of half the length; then this sum multiplied by its square root gives the cube of the diagonal. This and many other useful calculations can be very conveniently done by means of the common, or carpenter's slide-rule.

[2] *Discharge of water through a sluice.*—Multiply breadth of opening by the height; this gives the area of the sluice.

Discharge = area, multiplied by five times the square root of head of water in feet.—The head of water is the difference of level of the water above and below the dam, if the sluice be entirely under the lower level; or the height of the upper level above the centre of the opening, if the sluice be above the lower level.

[3] *Discharge of water over a weir one foot in length.*—If the weir is more or less than a foot, multiply the quantity in the table opposite the given depth by the length of the weir in feet, or decimals of a foot.

Depth falling over, inches.	Discharge per minute.	Depth falling over, inches.	Discharge per minute.
½	1.70 cubic feet.	2½	19.70 cubic feet.
1	4.82 " "	3	26.62 " "
1½	8.84 " "	3½	33.22 " "
2	13.63 " "	4	40.71 " "

Thus, if the weir measure 1 foot, and the depth of water falling over be 2 inches, the delivery is read at once, viz., 13.63 cubic feet, or 84.9 gallons per minute.

four-fifths of the surface-velocity (being nearly the proportion of mean to surface velocity), and multiply by the sectional area. The result will be the yield of the stream per second.

It may sometimes be worth while, if labor be at hand, to remove some of the irregularities of the channel, or even to dig a new one across the neck of a bend in the course of the stream.

The yield of a spring or small river should be determined several times, and at different periods of the day.

Wells.—The yield of wells can only be known by pumping out the water to a certain level and noticing the length of time required for refilling. In cases of copious flow of water, a steam-engine is necessary to make any impression; but, in other cases, pumping by hand or horse labor may be sufficient perceptibly to depress the water, and then, if the quantity taken out be measured, and the time taken for refilling the well be noted, an approximate estimate can be formed of the yield.

Permanence of Supply.—It is obvious that the permanence of the supply of a spring or small stream may often be of the greatest moment in the case of an encampment, or in the establishment of a permanent station.

In the first place, evidence should, when available, be obtained. If no evidence can be got, and if the amount and period of rain be not known, it is almost impossible to arrive at any safe conclusion. The country which forms the gathering ground for the springs or rivers should be considered. If there be an extensive background of hills, the springs toward the foot of the hills will probably be permanent. In a flat country the permanency is doubtful, unless there be some evidence from the temperature of the spring that the water comes from some depth. In limestone regions springs are often fed from subterranean reservoirs, caused by the gradual solution of the rocks by the water charged with carbonic acid; and such springs are very permanent. In the chalk districts there are few springs or streams, on account of the porosity of the soil, unless at the point the level be considerably below that of the country generally. The same may be said of the sandstone formations, both old and new; but deep wells in the sandstone often yield largely, as the permeable rocks form a vast reservoir. In the granitic and trap districts, small streams are liable to great variations, unless fed from lakes; springs are more permanent when they exist, being perhaps fed from large collections or lochs.

2. Storage.

The amount of storage required will depend on circumstances, viz., the amount used, and the ease of replenishing. It is, of course, easy to calculate the space required when these conditions are known, in this way:—The number of gallons required daily for the whole population must be divided by 6.23 to bring into cubic feet, and multiplied by the number of days which the storage must last; the product is the necessary size of the reservoir in cubic feet.

Many waters, particularly rain water, must be filtered through sand before they pass into small cisterns, and the filter should be cleaned every three or four months. Fig. 1 is a single filter recommended by the Barrack Commission.[1]

A double filter can be made by having a second chamber.

Whatever be the size of the reservoir, it should be kept carefully clean,

[1] Report on the Mediterranean Stations, 1863.

and no possible source of contamination should be permitted. In the large reservoirs for town supply, the water is sometimes rendered impure by floods washing surface refuse into them, or by substances being thrown in. In fact, in some cases, water pure at its source becomes impure in the reservoirs.

Some large cities are still supplied principally by rain-water, as Constantinople,—where under the houses are enormous cisterns,—Venice, and other places. Gibraltar and Malta are in part supplied in this way.

As far as possible, all reservoirs, tanks, etc., should be covered in and ventilated; in form they should be deep rather than extended, so as to lessen evaporation, and secure coolness. Though they should be periodically and carefully cleaned, it would appear that it is not always wise to disturb water-plants which may be growing in them; some plants, as the *Protococcus*, the *Chara*, and others, give out a very large amount of oxygen, and thus oxidize and render innocuous the organic matter which may be dissolved in the water or volatilized from the surface.[1] Dr. Chevers men-

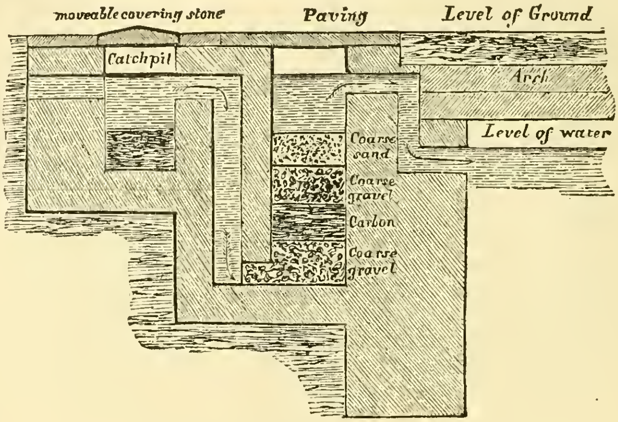

FIG. 1.

tions that the water of some tanks which were ordered to be cleared of water-plants by Sir Charles Napier, deteriorated in quality. Other plants, however, as some species of duckweed (*Lemna* at home, *Pistia* in the tropics), are said to contain an acrid matter which they give off to the water. It would be well to remove some of the plant, place it in pure water in a glass vessel, and try by experiment whether the amount of organic matter in the water is increased, or whether any taste is given to the water. The presence of some of the *Nostoc* family gives rise to an offensive pig-pen odor when decaying.[2] Dead vegetable matter should never find its way into, or at any rate remain in, the reservoir.

Whenever a reservoir is so large that it cannot be covered in, a second smaller covered tank, capable of holding a few days' supply, might be provided, and this might be fitted with a filter, through which the water of the large reservoir might be led as required.

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[1] Clemens, in Archiv. für Physiol. Heilk., 1853.

[2] Farlow, Supplement to First Annual Report of State Board of Health, etc., of Massachusetts, 1877, p. 143.

When tanks are large they are made of earth, stones, or masonry; if mortar be used, it should, as in the case of the smaller reservoirs, be hydraulic, so that it may not be acted on by the water.

The materials of small reservoirs and cisterns are stone, cement, brick, slate, tiles, lead, zinc, and iron. Glass-lined wooden cisterns have also been proposed. Of these slate is the best, but it is rather liable to leakage, and must be set in good cement or in Spence's metal; common mortar must not be used for stone or cement, as lime is taken up and the water becomes hard.[1] Leaden cisterns, as in the case of leaden pipes, often yield lead to water, and should be used as little as possible, or should be protected. Lead cisterns are corroded by mud or mortar, even when no lead is dissolved in the water. Iron cisterns and pipes are often rapidly eaten away; they are now sometimes protected by being covered inside with Portland cement or with a vitreous glaze. Crease's patent cement is a very useful covering. Barff's process of producing the magnetic oxide on the surface of iron is coming into use. Galvanized iron tanks are also very much used. They must be covered, and in India be protected from the sun. Zinc has been recommended, but water passing through zinc pipes, or kept in zinc pails, or in so-called galvanized iron vessels, may produce symptoms of metallic poisoning,[2] and even taste strongly of zinc salts, especially if the water is rich in nitrates. It would certainly be best to abandon lead, zinc, and galvanized iron as materials for cisterns, as much as possible; iron coated by the Barff process is much to be preferred.

Cisterns should always be well covered, protected as much as possible from both heat and light, and thoroughly ventilated, if they are of any size. Care should always be taken that there is no chance of leakage of pipes into them. A common source of contamination is an overflow pipe passing direct into a sewer, so that the sewer gases pass up, and being confined by the cover of the cistern, are absorbed by the water; to prevent this, the overflow pipe is curved so as to retain a little water and form a trap, but the water often evaporates, or the gases force their way through it; no overflow pipe should therefore open into a sewer, but should end *above* ground over a trapped grating.[3] A cistern supplying a water-closet should not be used to supply cooking and drinking water, as the pipes leading to the closet often conduct closet air to the cistern. Hence, a small cistern (water-waste preventer) should be used for each closet. Cisterns should be periodically and carefully inspected; and in every new building, if they are placed at the top of the house, convenient means of access should be provided.

Tanks to hold rain-water require constant inspection.

Wells (which are really reservoirs) are very liable to contamination from surface washings during rains. A good coping will often prevent this; but if there is much subsoil soaking, lining with iron to a certain depth, or covering with brickwork set in cement for a sufficient depth to arrest the flow, is desirable.

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[1] In two cases in Ireland (at Belturbet and Monaghan) so much lime was taken up from the lining of the tanks that the water was strongly alkaline and tasted caustic. See Report on Hygiene, Army Medical Reports, vol. xix., p. 170.—[F. de C.]

[2] Dr. Orsborn, formerly of Bitterne, has seen several cases of this kind. See also Downes, Sanitary Record, vol. ix., p. 333.

[3] For an instance of typhoid fever produced by this cause, see Lectures on State Medicine, by F. de Chaumont, pp. 76, 77. See also Dr. Blaxall's Report on Enteric Fever at Ilkeston in 1880.

3. Distribution.

When houses are removed from sources of water the supply should be by aqueducts and pipes. The distribution by hand is rude and objectionable, for it is impossible to supply the proper quantity, and the risks of contamination are increased. Some of the most extraordinary of the Roman works in both the Eastern and Western Empires were undertaken for the supply of water—works whose ruins excite the astonishment and should rouse the emulation of modern nations.

The plans for the distribution of water should include arrangements for the easy and immediate removal of dirty water. This is an essential point, for in many towns where houses are not properly arranged for small families, there are no means of getting rid of water from the upper rooms, and this inconvenience actually limits the use of water, even when its supply is ample.

The supply of water to houses may be on one of two systems, intermittent or constant. The difference between the two plans is, that in the first case there is storage in the houses for from one to three days ; while in the latter case there is either no storage, or it is only on a very small scale for two purposes, viz., for water-closets and for the supply of kitchen boilers.[1] It should, however, be understood that the constant supply has not always meant in practice an unlimited supply, nor has it been the case that the water in the house pipes was always in direct communication with the water in the reservoirs. On the contrary, the water to the houses has often been cut off, particularly in places where the supply was limited, and the fittings not good, and where there was great waste.

The great arguments against storage on the premises (except on a limited scale for closets and boilers) are the chances of contamination in cisterns, and the very imperfect means of storage. In poor houses wooden casks or barrels are often used, and may be placed in the worst situations. Although the arguments against the storage system are directed in part against removable failures, it must, however, be admitted that, especially in poor houses, the inspection and cleansing even of a well-placed cistern will never be properly done, and that with all precautions the chances of contamination of the water during storage are very great. As regards this point, the constant system has a very great superiority, for there is no chance for contamination except in the reservoir or in the pipes. So great an advantage is this in a sanitary point of view, that almost all those who have paid most attention to sanitary affairs have advocated the constant system. It is, however, quite necessary that it should be understood what the constant system sometimes has been in practice. When there is an abundance of water, as at Glasgow, the stoppages of water may have been few, but when water has had to be economized, the water has been from time to time shut off from the house pipes, and then no water has been procurable for hours. This, however, is avoided as much as possible in the day time, so that the inconvenience is reduced to a minimum. In some cases, again, in order to economize water, a throttle or ferrule has been in-

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[1] Much valuable evidence on the constant supply may be found in the Report of the House of Commons Committee on the East London Water Bills, 1867. It is curious to see how difficult the definition of a constant supply was found to be. The difference of opinion between engineers on the desirability of a constant supply is shown to be considerable. The statements in the text are drawn from a collation of this evidence, and from a consideration of Mr. Bateman's pamphlet, and many other works.

troduced into the communication or house pipe,[1] lessening the diameter to $\frac{1}{8}$th or even to $\frac{1}{16}$th of an inch, or smaller, so that if the head of pressure be small the water flows very slowly, and sometimes merely dribbles. In other cases, a meter is put on a pipe communicating with several houses; and the owner of the houses is charged for the water, and this leads him to enforce a very sparing use of it. In all these ways the constant system may tell against the consumer, while, on the other hand, great waste, leaking fittings, and fraudulent abstraction of water (to avoid which there are several ingenious contrivances) tell against the company, and lead to a depreciation of their property.

In spite of all these difficulties the system of constant supply, in some shape or other, has been carried out in about 150 towns in England;[2] and the Metropolis Water Act of 1871 ordered constant supply for London, if demanded by the ratepayers, and if proper fittings are provided.

In providing a constant supply, certain precautions are necessary. The fittings must be as perfect as possible. In some cases, when the system has been changed from the intermittent to the constant system, as in Chester, the waste of water has been so great that the old plan has been recurred to. But when the fittings are good there is real economy in the constant system,—as shown by the comparison between Lincoln and Oxford, and by Hawksley's evidence with reference to Norwich.[3] Common taps do not answer, and the best screw taps and fittings must be used.[4] To prevent theft, it has been proposed to make the removal of fittings a specific offence, punished summarily by imprisonment, and to place the sale of such property under the same restrictions as in the case of Crown property.

One important sanitary advantage of the constant system is that, in order to facilitate inspection and detection of waste, no waste-pipe is allowed to open into a sewer, but it is always so placed that any escape of water can be easily seen (the so-called warning pipe). The great evil of sewer gases being conducted back into houses through overflow pipes is thus avoided. Careful inspection and good fittings so far lessen the waste of the constant system, that in some cases less water is used than under the intermittent plan.[5]

Mr. G. Deacon, in a very interesting and instructive paper,[6] has shown that the loss on the constant system is due to causes over which the consumer has generally little or no control, and that it occurs for the most part before the water reaches him. It arises chiefly from leaks in pipes, drawn joints, and so on, and up to lately there was no means of detecting this in a way practically useful. By the introduction of his water-waste meter this is now done with the utmost precision and accuracy, so that now in Liverpool the expenditure of water has been reduced from 33.5 gallons per head per diem to 13.3. This does not mean any restriction to the con-

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[1] The terms used to describe the pipes differ a little apparently; the mains and district or sub-mains are the large pipes, which are always full of water, the latter being of course the smaller; the service-pipe is another term for a district main. The communication-pipe is that which runs from the service-pipe to the house, and in the house it takes the name of house-pipe.

[2] Mr. Beggs' Pamphlet, op. cit., p. 20.

[3] See Report of Rivers Pollution Commission, vol. vi., p. 233.

[4] A bad ball-cock has been known to drop 12 gallons a day.

[5] Evidence of Mr. Easton in the Report of Committee on the East London Water Bills, 1867.

[6] The Constant Supply and Waste of Water, by George F. Deacon, M. Inst. C. E., Journal of the Society of Arts, vol. xxx., p. 738, 1882.

sumer; the supply is now absolutely constant and the use unlimited. But it means that formerly the consumer used only 13 gallons at the outside, whilst 20 gallons went to pure waste. Mr. Louttit[1] stated that the Lambeth Water Company was able by this means to reduce the expenditure from 35.09 to 15.28 per head. The general waste in London appears to be about 15 gallons per head out of a total of about 35. With such a system of checking, the main difficulties of a constant supply seem to be solved, even if every consumer used the full 25 gallons laid down in this work.

Some engineers have proposed what may be called a compromise between the intermittent and constant systems. The objection to this plan is that cisterns are reintroduced, and their lessened size does not remove the objections to them.

If the constant system is used, a good screw stop-cock, available to the tenant, should be placed at the point of the entrance of the pipe into the house, so that the water may be turned off if pipes burst, or to allow the pipes to be empty, as during frost. Every precaution must be taken that impure water is not drawn into the pipes by a pipe being emptied and sucking up water from a distance.[2]

For the supply of a very large city, it might be desirable to divide the city into sections, and to establish a reservoir for each district, holding three or four days' supply. In this way the waste of one section would not take away the water from another. In some instances, people in one part of a town, supplied on the constant system, have used so much water for gardens that other parts have been altogether deprived of supply. The system of secondary reservoirs would not only lessen this chance, but would make it possible to ascertain that every part of the town was getting its supply. The number of water companies in London has in fact somewhat this effect, but the subdivision is not carried far enough.

There is no doubt that the constant system is the safer, especially for poor houses, as it leaves no loophole for inattention in the cleansing of cisterns. Only, it requires that the constant system should really fulfil the

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[1] Discussion on Mr. Deacon's paper.

[2] The Board of Trade issued a Minute in 1872, laying down regulations and defining the kind of fittings and arrangements for London. The following are the principal points: lead pipes to be of certain strength (if internal diameter is $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{5}{8}$ in., $\frac{3}{4}$ in., 1 in., $1\frac{1}{4}$ in., the respective weights per lineal yard are to be 5 lb, 6 lb, $7\frac{1}{2}$ lb, 9 lb, 12 lb, 16 lb). Every pipe in contact with the ground to be of lead; each house to have a communication pipe, but only one, unless an owner has it for a block of houses; connection of every communication pipe to be by a brass screwed ferule or stop-cock with a clear area of water-way equal to one-half inch, every joint to be a "plumbing" or "wipe" joint. No pipe to pass through an ash-pit, manure heap, drain, unless it cannot be avoided, and then the pipe is to be laid in an exterior cast-iron pipe or jacket; each pipe in the ground to be thirty inches below surface; each communication pipe to have near the entrance into the house a screwdown stop-valve: if in the ground such valve to be protected by proper cover and guard box; every cistern to be water-tight, to have a good "ball-tap;" no waste-pipe except a "warning pipe," and such warning pipe to be so placed as to be easily inspected. No cistern buried in ground to be used; wooden cisterns to have metallic linings; every water-closet, urinal, or boiler shall be served only from a cistern, and shall not be in direct communication with the water-pipes; closets and urinals to have water-waste preventers; every "down pipe" into a water-closet to have an internal diameter of not less than $1\frac{1}{4}$ inch, and to weigh not less than 9 lb per lineal yard. No bath to have an overflow pipe except of the "warning" kind; the outlet must be distinct from the inlet, and the inlet shall be higher than the highest stand of the water. Lead warning pipes of which the ends are open, and which cannot remain charged with water, may have the following minimum weight: $\frac{1}{2}$ inch in diameter to have a weight 3 lb per yard; $\frac{3}{4}$ in., 5 lb; 1 in., 7 lb.

conditions laid down for it, viz., it should deliver sufficient water at all times, and not merely delude us with a phrase.

In both plans the water is conducted from the reservoirs in pipes. The pipes are composed of iron, masonry, or earthenware, for the larger pipes or mains, the iron being sometimes tinned or galvanized, or lined with concrete, or pitched, or covered with a vitreous glaze, such as that patented by De Lavenant ; for the smaller pipes, iron, lead, tin, zinc, tinned copper, earthenware, gutta percha, etc., are used.

Pipes of artificial stone are now made. Iron is the best material for the larger pipes, and iron or non-metallic substances for the smaller pipes.

Water should be distributed not only to every house, but to every floor in a house. If this is not done, if labor is scarce in the houses of poor people, the water is used several times ; it becomes a question of labor and trouble *versus* cleanliness and health, and the latter too often give way. Means must also be devised for the speedy removal of dirty water from houses for the same reasons. In fact, houses let out in lodgings should be looked upon, not as single houses, but as a collection of dwellings, as they really are.

ACTION OF WATER ON LEAD PIPES.

There are more discrepancies of opinion on this subject than might have been anticipated.

From an analysis of most of the works, the following points appear to be the most certain :—

1. The waters which act most on lead are the purest and most highly oxygenated ; also those containing organic matter, nitrites (Medlock),[1] nitrates,[2] and according to several observers, chlorides.[3] Besides the portion dissolved, a film or crust is often formed, especially at the time of contact of water and air ; this crust consists usually of two parts of lead carbonate and one part of hydrated oxide. The mud of several rivers, even the Thames, will corrode lead, probably from the organic matter it contains, but it does not necessarily follow that any lead has been dissolved in the water. Bits of mortar will also corrode lead.

2. The waters which act least on lead are those containing carbonic acid,[4] calcium carbonate, calcium phosphate (which has been found by Frankland to have a great protective power), and in a less degree calcium sulphate, and perhaps, in a still less degree, magnesian salts, and the alkaline phosphates ;[5] but it has been said that perfectly pure water, containing no gases, has no action on lead. This, however, is not strictly correct, as pure distilled water has been known at Netley to take up lead from a leaden pipe. The deposit which frequently coats the lead consists of car-

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[1] Medlock attributes the greatest influence to ammonium nitrite formed from organic matter ; lead nitrite is rapidly formed, and carbonate is then produced ; the nitrous acid being set free to act on another portion of lead. The ammonium nitrite exists in most distilled water.

[2] Pattison Muir attributes very powerful action to nitrates, but says that it is modified or even arrested by the presence of carbonates, sulphates, and chlorides, but there is some discrepancy of opinion as to the action of the chlorides.

[3] Pattison Muir found that a solution of sulphate or chloride of ammonium of 0.04 per cent. took up 2.2 grains per gallon after exposure to lead for 505 hours.

[4] M. Langlois (Rec. de Mém. de Med. Mill, 1865, p. 412) attributes a great action on lead to the carbonic acid, but states that the carbonate of lime entirely protects lead, apparently by rendering the carbonic acid inactive.

[5] Report of the Government Commission, 1851, p. 7.

bonate, phosphate, and sulphate of lead, calcium, and magnesium, if the water have contained these salts, and lead chloride.[1]

3. From the observations of Graham, Hofmann, and Miller, the protective influence of carbonic acid gas appears to be very great; a difficultly soluble lead carbonate is formed. However, a very great excess of free carbonic acid may dissolve this. This has perhaps led to the statement that carbonic acid counteracts the preservative effects of the salts. Water charged with carbonic acid under pressure has a very marked solvent action on lead (Pattison Muir).

Other substances may find their way into water which may act on lead —as vegetable and fatty acids, arising from fruits, vegetables, etc., or sour milk or cider, etc.

4. The lead itself is more easily acted upon if other metals, as iron, zinc, or tin, are in juxtaposition; galvanic action is produced. Bending lead pipes against the grain, and thus exposing the structure of the metal, also increases the risk of solution; zinc pipes, into the composition of which lead often enters, yield lead in large quantities to water, and this has been especially the case with the distilled water on board ships.

AMOUNT OF DISSOLVED LEAD WHICH WILL PRODUCE SYMPTOMS OF POISONING.

Dr. Angus Smith refers to cases of lead paralysis in which as little as $\frac{1}{100}$th of a grain per gallon was in the water. Adams[2] also speaks of $\frac{1}{100}$th of a grain causing poisoning. Graham speaks of $\frac{1}{57}$th of a grain per gallon as being innocuous. Angus Smith says that $\frac{1}{40}$th of a grain per gallon may affect some persons, while $\frac{1}{10}$th of a grain per gallon may be required for others.[3] But it is difficult to prove it may not at some time have been more than this. Calvert found that water which had been decidedly injurious in Manchester contained from $\frac{1}{10}$th to $\frac{3}{10}$ths of a grain per gallon.

In the celebrated case of the poisoning of Louis Philippe's family at Claremont, the amount of lead was $\frac{7}{10}$ths of a grain per gallon; this quantity affected 34 per cent. of those who drank the water.

The water of Edinburgh is said to contain only $\frac{1}{140}$th of a grain per gallon, which is not hurtful.[4]

On the whole, it seems probable that any quantity over $\frac{1}{20}$th of a grain per gallon should be considered dangerous, and that some persons may even be affected by less quantities.[5]

PROTECTION OF LEAD PIPES.

The chief means which have been proposed are :—

(*a*) Lining with tin. Calvert's experiments[6] show that extra tinned and ordinary tinned lead piping both gave up lead to the pure water now used at Manchester.

(*b*) A much better plan is by having a good block-tin pipe enclosed in a lead pipe, as in Haines' patent. If the tin is good, it is little acted on, and the strength of the pipe is increased, while bends and junctions can be

[1] Lauder Lindsay, Action of Hard Water on Lead, p. 7.

[2] Trans. of the American Medical Society, 1852, p. 163.

[3] Wanklyn adopts $\frac{1}{10}$th of a grain per gallon as justifying rejection of a water; $\frac{1}{20}$th would probably be a safer limit.

[4] Chemical News. September 28, 1861.

[5] See also Taylor's Med. Jurisp., 1865, p. 242; and opinions of Penny, ibid, p. 241.

[6] Chemical News, September 28 1861.

made without destroying the continuity of the tin. The composite pipes of this kind made by Messrs. Walker, Parker & Co. are said to withstand any amount of torsion. On the authority of Professor J. Emerson Reynolds, F.R.S., it is said that lead alloyed with 3 per cent. of tin is not acted upon by water;[1] pipes of this kind appear to be used in Dublin and in Glasgow. Later experience with this alloy, however, seems to have modified the good opinion first held of it; it is certainly inapplicable to cisterns, or for any purpose where it is more or less exposed to the air.

(*c*) Fusible metal, viz., lead, bismuth, and tin. This is certainly objectionable.

(*d*) Bituminous coating (M'Dougall's patent). This is said to be effectual, but no exact experiments have been recorded.

(*e*) Various gums, resins, gutta-percha, and india-rubber. These would probably be efficacious, but there does not seem to be any evidence to show how long they will adhere.

(*f*) Coating interior of pipes with lead sulphide by boiling the pipes in sodium sulphide for fifteen minutes. The sodium sulphide may be made by boiling sulphur in liquor sodæ. (Schwartz's patent.)

(*g*) Varnish of coal tar.[2]

SUBSTITUTES FOR LEAD PIPES.

Cast and wrought iron pipes can be used, and Mr. Rawlinson now orders no others. The iron can be glazed internally.[3] Copper tinned and block-tin are also employed, and both are excellent, but are rather expensive. In some cases the tin is eaten through, but this is not common.[4]

SECTION II.

QUALITY OF DRINKING WATER.

SUB-SECTION I.—COMPOSITION.

The composition of water is of importance for several economic purposes; for certain trades which require careful processes of washing and dyeing; for the supply of engines, etc. But these subjects are too technical to be discussed here, and this chapter is therefore restricted to the quality of water as used for drinking purposes. The only domestic matter of importance connected with quality, apart from drinking and cooking, is the relative amount of soap used by hard and soft water in washing. But this is so obvious a matter that it only requires to be alluded to.

Owing to many of the domestic uses of water, such as the washing of

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[1] Manual of Hygiene for Ireland, p. 218. Professor Cameron, of Dublin, corroborates this statement, Manual of Hygiene, p. 86.

[2] Lauder Lindsay, Action of Hard Water on Lead, p. 21.

[3] Iron pipes coated inside with Angus Smith's bituminous varnish are a good deal used. In experiments made at Netley these were found to yield a distinct taste of tar to the water for a considerable time; after a time, however, this action was much diminished, but did not entirely cease. Probably Barff's process of producing a surface of magnetic oxide on iron will come into use. For joining pipes Spence's metal will probably prove useful.

[4] I have seen block-tin pipes eaten through by water at Woolston, apparently in consequence of the presence of nitrates. Zinc pipes, which have been recommended, are objectionable as likely to yield poisonous salts to such waters.—[F. de C.]

utensils, the supply for closets, etc., not requiring a very pure water, it has been proposed in some cases to supply water from two sources—one pure for drinking and cooking, the other impure. This requires, however, two sets of pipes, and involves the chance of mistake between two waters; and it is only likely to be of use under exceptional circumstances.

Drinking water is supplied from shallow, deep, and Artesian well sources: rain, rivers, wells, springs, etc.

Rain Water.—As it falls through the air, rain becomes highly aërated (average, 25 cubic centimetres per litre), the oxygen being in larger proportion than in atmospheric air (32 per cent., or a little more); carbon dioxide constitutes 2½ or 3 per cent. of the gas. It carries down from the air ammoniacal salts (carbonate, nitrite, and nitrate), and nitrous and nitric acids in small amount. The total quantity of nitrogen in ammoniacal salts, nitrous and nitric acid, is .0985 parts per 100,000. Frankland puts the average at .032. At Montsouris,[1] mean of seven years, the ammonia amounted to .193 per 100,000, or 9.135 grs. per gallon; the nitric acid (NO_3), mean of six years, to .354 per 100,000, or .248 per gallon. This gives a total nitrogen, from ammonia and nitric acid, of .239 per 100,000. In towns with coal-fires it takes up sulphurous and sulphuric acids, and sometimes hydrogen sulphide. The sulphates in rain increase, according to Dr. Angus Smith,[2] as we pass inland, and before large towns are reached; they are, according to this author, "the measure of the sewage in air" when the sulphur derived from the combustion of coal can be excluded, but in this country the exclusion could never be made. Free acids are not found with certainty, according to Smith, when combustion and manufactures are not the cause. The acidity taken as sulphuric anhydride was equal to .0097 grain per gallon of rain in a country place in Scotland, and 1.0589 grain in Glasgow; in Manchester in 1870 it was .8416, and in London, .2713 grain. The nitric acid in Glasgow was as much as .1705 grain per gallon, and in London only .06188. Albuminoid ammonia was no less than .326 part in a million in London rain.[3] Rain also carries down many solid substances, as sodium chloride, in sea air; calcium carbonate, sulphate, and phosphate; ferric oxide; carbon.[4] It almost always contains also a little nitrogenous organic matter, amounting in extreme cases to as much as .35 grain per gallon. The total amount of solids from five analyses quoted by Moleschott, was 0.032 gramme per litre, or 224 grains per gallon, and from 63 samples by Frankland, 3.86 per 100,000, or 2.701 per gallon.[5]

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[1] Annuaire de l'observatoire de Montsouris pour l'an 1882.

[2] Air and Rain, 1872, p. 245.

[3] Angus Smith, op. cit , p. 363.

[4] An ingenious plan for removing suspended matter from rain-water is supplied by Buck's "Patent Percolator," which may be attached to the pipe supplying a rain-water tank. It works automatically and produces good results, although at the expense of considerable waste of the water.

[5] In rain-water collected at St. Albans, in the middle of an arable field, two feet from the ground, Frankland found as much as 8.58 parts in 100,000 or 6.006 grains per gallon; from the roof of the Land's End Hotel (Cornwall) 42.8 per 100,000, of which one-half was chlorides.

In a sample from supply tank in officers' quarters at Portland I found 47.95 gr. per gallon of solids, of which about 10 were chlorides; the organic constituents were also very large. In another sample, gathered as collected, 32.55 total solids and 14 chlorides; and in one from a pipe leading to the cookhouse, 59.25 total solids and 15.2 chlorides. In a sample collected through funnels direct into glass bottles, the solids were 6.65 per gallon, of which 4.9 were volatile, chiefly ammonium chloride, etc.—[F. de C.]

Occasionally microscopic plants of the lowest order (as *Protococcus pluvialis* and others) are present, and in towns the *débris* arising from street dust.

With regard to Rain as a Source of Supply.—The uncertainty of the rainfall from year to year, the length of the dry season in many countries, and the large size of the reservoirs which are then required, are disadvantages. On the other hand, its general purity and its great aëration make it both healthy and pleasant. The greatest benefits have resulted in many cases (especially in some of the West Indian Islands) from the use of rain instead of spring or well water, which is often largely impregnated with earthy salts. In all places where the spring or well water is thus bad, as in the neutral ground at Gibraltar, rain-water should be substituted. So also it has been suggested that in outbreaks of cholera anywhere, the rain-water is less likely to become contaminated with sewage matters than wells or springs, into which organic matters often find their way in an unaccountable manner.

Ice and Snow Water.—In freezing, water becomes purer, losing a large portion of its saline contents. Even calcium carbonate and sulphate are partially got rid of. The air is at the same time expelled. Ice-water may thus be tolerably pure, but heavy and non-aërated. Snow-water contains the salts of rain-water with the exception of rather less ammonia. The amounts of carbonic acid and air are very small.

There has long been an opinion that snow-water is unwholesome, but this, if it be true, is probably due to impurities. Ice and snow often contain a good deal of suspended organic matter. Dr. Baker Edwards of Montreal found 2 grains per gallon in the shore ice and 1 grain per gallon in the river ice.[1] In Northern Europe, the poor classes have the habit of taking the snow lying about their dwellings, and as this is often highly impure with substances thrown out from the house, this water may be unwholesome. It has been conjectured that the spread of the cholera in the Russian winter in 1832 was owing to the use of such snow-water contaminated by excretions. Ice and snow may also be the means of conveying malarious poison to places at a distance.[2]

Dew has occasionally been a source of supply to travellers in sterile regions in South Africa and Australia, on board ship.

Spring, Well, and River Water.—The rain falling on the ground partly evaporates, partly runs off, and partly sinks in. The relative amounts vary with configuration and density of the ground, and with the circumstances impeding or favoring evaporation, such as temperature, movement of air, etc. In the magnesian limestone districts, about 20 per cent. penetrates; in the new red sandstone (Triassic), 25 per cent.; in the chalk, 42; in the loose Tertiary sand, 90 to 96.

Penetrating into the ground, the water absorbs a large proportion of carbonic acid from the air in the interstices of the soil, which is much richer (250 times) in CO_2 than the air above. It then passes more or less deeply into the earth, and dissolves everything it meets with which can be taken up in the time, at the temperature, and by the aid of carbonic acid. In some sandy soils there is a deficiency of CO_2, and then the water is also wanting in this gas, and is not fresh and sparkling.

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[1] Further evidence of the impurity to be sometimes met with in ice will be found in the Reports of the State Board of Health of Massachusetts, vols. vii. and x.

[2] See paper by C. Smart, M.B., C.M., Captain and Assistant-Surgeon, United States Army, "On Mountain Fever and Malarious Water," American Journal of the Medical Sciences, Jan., 1878. See also Report on Hygiene, A.M.D. Reports, vol. xix.

The chemical changes and decompositions which occur in the soil by the action of carbonic acid, and which are probably influenced by diffusion, and perhaps pressure, as well as by temperature, are extremely curious,[1] but cannot be entered upon here. The most common and simple are the solution of calcium carbonate, and the decomposition of calcium and sodium silicate by carbonic acid, or alkaline carbonates. Salts of ammonia, also, when they exist, appear from Dietrich's observations to have a considerable dissolving effect on the silicates.

Fed from a variety of sources, river-water is even more complex in its constitution than spring-water; it is also more influenced by the season, and by circumstances connected with season, such as the melting of snow or ice, rains and floods, etc. The water taken on opposite sides of the same river has been found to differ slightly in composition.

The general result of solution and decomposition is, that the water of springs and rivers often contains a great number of constituents—some in very small, others in great amount. Some waters are so highly charged as to be termed mineral waters, and to be unfit for drinking, except as medicines. The impurities of water are not so much influenced by the depth of the spring as by the strata it passes through. The water of a surface spring, or of the deepest Artesian well, may be pure or impure. The temperature of the water also varies, and is chiefly regulated by the depth. The temperature of shallow springs alters with the season; that of deeper springs is often that of the yearly mean. In very deep springs, or in some Artesian wells, the temperature of the water is high.

The substances which are contained in spring, river, and well waters are noted more fully under the head of "EXAMINATION OF WATER." There may be suspended matters, mineral, vegetable, or animal; dissolved gases, viz., nitrogen, oxygen, carbon dioxide, and in some cases hydrogen sulphide, and carburetted hydrogen; and dissolved solid matters, consisting of lime, magnesia, soda, potassa, ammonia, iron, alumina, combined with chlorine, and sulphuric, carbonic, phosphoric, nitric, nitrous, and silicic acids. More infrequently, or in special cases, certain metals, as arsenic, manganese, lead, zinc, and copper, may be present.

The mode of combination of these substances is yet uncertain; it may be that the acids and bases are equally distributed among each other, or some other modes of combination may be in play. The mode of combination may *usually* be assumed to be as follows. The chemist determines the amount of each separate substance, and then calculates the combination as follows. The chlorine is combined with sodium; if there is an excess, it is combined with potassium or calcium; if there is an excess of soda, it is combined with sulphuric acid, or if still in excess, with carbonic acid. Lime is combined with excess of chlorine, or sulphuric acid, or if there be no sulphuric acid, or an excess of lime, with carbonic acid. Magnesia is combined with carbonic acid. So that the most usual combinations are sodium chloride, sodium sulphate, sodium carbonate, calcium carbonate (held in solution by carbonic acid), calcium sulphate, calcium chloride and silicate, and magnesium carbonate; but the results of the analysis may render other combinations necessary.

Distilled Water.—Distillation is now very largely used at sea, and affords an easy way of getting good water from sea or brackish water. Almost

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[1] These are given in detail by G Bischof, Chemical and Physical Geology (Cavendish Society's edit.), 1854, vol. i., p. 2 et seq.; and in Watt's Dictionary of Chemistry, Article "Chemistry of Geology," by Dr. Paul.

any form of apparatus will suffice, if fuel can be procured, to obtain enough water to support life ; and if even the simplest appliances are not attainable, the mere suspension of clean woollen clothing over boiling water will enable a large quantity to be collected. At sea, salt water is sometimes mixed with it from the priming of the boilers, and occasionally from decomposition of magnesium chloride (probably), a little free hydrochloric acid passes off. This can, if necessary, be neutralized by sodium carbonate.

As distilled water is nearly free from air, and is, therefore, unpalatable to some persons, and is supposed indigestible,[1] it may be aërated by allowing it to run through a cask, the bottom of which is pierced with fine holes, so as to expose the water to the air. Plans for aërating the water distilled from sea-water have been proposed by Normandy and others, and are used in many steamers. Organic matter, at first offensive to taste and smell in distilled water, can be got rid of by passing through a good filter, or by keeping three or four days, or by the addition of a little permanganate solution.

Care should be taken that no lead, zinc, or copper finds its way into the distilled water. Many cases of lead poisoning have occurred on board ships, partly from the use of *minium* in the apparatus, and partly from the use of *zinc pipes* containing lead in their composition. If possible, *block tin* should always be used.

Comparative Value of Spring, River, and Well Water as Sources of Supply.

This depends on many circumstances. Spring-water is both pure and impure in different cases ; and the mere fact of its being a spring is not, as sometimes imagined, a test of goodness. Frequently, indeed, river-water is purer than spring-water, especially from the deposit of calcium carbonate ; organic matter is, however, generally in greater quantity, as so much more vegetable matter and animal excreta find their way into it. The water of a river may have a very different constitution from that of the springs near its banks. A good example is given by the Ouse, at York : the water of this river is derived chiefly from the millstone grit which feeds the Swale, the Ure, and the Nid, tributaries of the Ouse ; the water contains only 9 grains per gallon of salts of calcium, magnesium, sodium, and a little iron. The wells in the neighborhood pass down into the soft red sandstone (Yoredale series) which lies below the millstone grit ; the water contains as much as 64.96 grains, and even, in one case, 96 grains per gallon ; in addition to the usual salts, there is much calcium chloride and calcium, sodium, and magnesium nitrates. Shallow well-water is always to be viewed with suspicion ; it is the natural point to which the drainage of a good deal of surrounding land tends, and heavy rains will often wash many substances into it.[2] The question may arise as to what should be considered a shallow, and what a deep well. In the *Rivers Pollution Commissioners' Sixth Report* all the shallow wells examined are less that 50 feet deep ; most of the deep wells more than 100 feet deep. Any well less than 50 feet deep that does not pass through an impermeable stratum, such as stiff clay or

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[1] By some even dangerous (Gerardin).

[2] Dr. Cameron (Dublin Journal of Medical Science) cites a case where good and bad water were obtained from different levels in the same well. Similar results have been observed elsewhere; see analysis of water from a well at Fareham, Report on Hygiene, A.M.D. Reports, vol. xxi. In these cases both samples were impure, but the water from the bottom of the well contained a great excess of salts, due probably to infiltration from the tidal waters of the neighboring river.

hard rock, must be classed as a shallow well. The following table is given by the Rivers Pollution Commissioners :—[1]

Wholesome	1. Spring-water, . .	very palatable.
	2. Deep well-water, .	
	3. Upland surface-water,	moderately palatable.
Suspicious	4. Stored rain-water, .	
	5. Surface-water from cultivated land, . .	palatable.
Dangerous	6. River-water, to which sewage gains access,	
	7. Shallow well-water, ...	

Sub-Section II.—Characters and Classification of Drinking Waters.

The general characters of good water are easily enumerated. Perfect clearness; freedom from odor or taste; coolness; good aëration; and a certain degree of softness, so that cooking operations, and especially of vegetables, can be properly performed, are obvious properties. But when we attempt a more complete description, and assign the amounts of the dissolved matters which it is desirable should not be exceeded, we find considerable difference of opinion, and also a real want of evidence on which to base a satisfactory judgment.

Still an hygienic classification or enumeration of potable waters, based on such facts as are generally admitted, will be useful. A division of waters used for drinking into four classes has been adopted in this work :—

1. Pure and wholesome water.
2. Usable "
3. Suspicious "
4. Impure "

The waters belonging to the first and second class may be used; those of the third, or suspicious class, should be well filtered before distribution, and, if possible, should be again filtered in the house. A purer source should also be obtained if possible, and sources of sewage contamination ascertained and prevented.

The waters of the fourth class should be entirely disused, or only be used when a better source is not procurable, and means of purification should then be systematically resorted to.

Sub-Section III.—Origin of the Impurities in Drinking Water.

The origin of the impurities in water may be conveniently referred to four heads, viz. :—(1) Substances derived from the source; (2) Substances added during the flow of the waters in rivers, canals, aqueducts, or other conduits; (3) Impurities caused by storage in reservoirs or tanks; and (4) Substances added during distribution from reservoirs either in pipes or water barrels, or in house cisterns.

1. Impurities of Source.

The geological formation of a district necessarily influences the composition of the water running through it, though it is impossible to tell with absolute certainty what the constituents of the water may be. Formations vary greatly, and the broad features laid down by geologists do

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[1] Sixth Report, p. 129.

not always suffice for our purpose. In the middle of a sandy district, yielding usually a soft water, a hard selenitic water may be found; and instead of the pure calcium carbonate water, a chalk well may yield a water hard from calcium sulphate and iron. Still it may be useful to give a short summary of the best known facts.

1. *The Granitic, Metamorphic, Trap-Rock, and Clay-Slate Waters.*—Generally the granitic water is very pure, often not containing more than 2 to 6 grains per gallon of solids, viz., sodium carbonate and chloride, and a little lime and magnesia. The organic matter is in very small amount. The clay-slate water is generally very pure, often not containing more than from 3 to 4 grains per gallon. The water from hard trap-rocks is pure, but if the trap be disintegrated the shallow wells sunk in it are of course liable to be fouled by surface washings or soakage.

2. *The Water from Millstone Grit and Hard Oolite.*—Like the granitic water this is very pure, often not containing more than 4 to 8 grains per gallon of mineral matters, which consist of a little calcium and magnesium sulphate and carbonate; a trace of iron.

3. *Soft Sand-Rock Waters.*—These are of variable composition, but as a rule are impure, containing much sodium chloride, sodium carbonate, sodium sulphate, iron, and a little lime and magnesia, amounting altogether to from 30 to 80 grains per gallon. The organic matter may be in large amount—4 to 8 grains per gallon, or even more. Sometimes these waters are pure and soft, but in other cases wells or springs, within a short distance, may vary considerably in composition.

4. *The Loose Sand and Gravel Waters.*—In this case there is also a great variety of composition. Sometimes the water is very pure, as in the case of the Farnham waters, and in some of the waters from the green sand, where the total solids are not more than from 4 to 8 grains per gallon, and consist of a little calcium carbonate, sulphate, and silicate; magnesium carbonate; sodium and potassium chloride; sodium and potassium sulphate; iron, and organic matter. The last is sometimes in some amount, viz., .8 to 1.8 grain per gallon. In tolerably pure gravels, not near towns, the water is often very free from impurity. In the case of many sands, however, which are rich in salts, the water is impure, the solid contents amounting sometimes to 50 or 70 grains per gallon, or more, and consisting of sodium chloride, sodium carbonate, sodium sulphate, with calcium and magnesium salts.[1] These waters are often alkaline, and contain a good deal of organic matter. The water from the sands in the "Landes" (Southern France) contains enough organic matter to give ague.

5. *Waters from the Lias Clays* vary in composition, but are often impure; even 217 grains per gallon of mineral matters have been found. No less a quantity than 88 grains of calcium sulphate, and 41.8 of magnesium sulphate, existed in a water examined by Voelcker.[2]

6. *The Chalk Waters.*—The pure, typical, calcium carbonate water from the chalk is very sparkling and clear, highly charged with carbonic acid, and contains from 7 to 20 grains per gallon of calcium carbonate, a little magnesium carbonate and sodium chloride—small and immaterial quantities of iron, silica, potassa, nitric, and phosphoric acids. Sulphuric

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[1] In a shallow well (20 feet deep) in the gravel, near Netley Abbey, the water yielded total solids 148.75, of which were chlorides 86.80 grains per gallon; after deepening it to 30 feet, and passing through a stratum of stiff blue clay, it gave only 16.8 total solids, and 6.5 of chlorides.—[F. de C.]

[2] In a well from Weedon Barracks, 109 feet deep, sunk in blue lias, I found 91 grains per gallon of solids, but very little organic matter.—[F. de C.]

acid in combination is sometimes present in variable amount; organic matter is usually in small amount. This is a good, wholesome, and pleasant water. It is hard, but softens greatly by boiling.[1]

7. *The Limestone and Magnesian Limestone Waters.*—These are also clear sparkling waters of agreeable taste. They differ from the chalk in containing usually more calcium sulphate (4 to 12 grains, or even more) and less carbonate, and, in the case of the dolomitic districts, much magnesium sulphate and carbonate. Organic matter is usually in small amount. They are not so wholesome as the chalk waters. They are hard, and soften less on boiling.

8. *The Selenitic Waters.*—Water charged with calcium sulphate (6 to 20 grains, or even more) may occur in a variety of cases, but it may sometimes come from selenitic rocks. It is an unwholesome water, and in many persons produces dyspepsia and constipation, alternating with diarrhœa. It is hard, softens little on boiling, and is not good for cooking or washing.

9. *Clay Waters.*—Very few springs exist in the stiff clay; the water is chiefly surface, and falls soon into rivers; it varies greatly in composition, and it often contains much suspended matter, but few dissolved constituents, chiefly calcium and sodium salts.

10. *Alluvial Waters.*—(Alluvium is usually a mixture of sand and clay.) Generally impure, with calcium carbonate and sulphate, magnesium sulphate, sodium chloride and carbonate, iron, silica, and often much organic matter. Occasionally the organic matter oxidizes rapidly into nitrites, and if the amount of sodium chloride is large, it might be supposed that the water had been contaminated with sewage. The amount of solids per gallon varies from 20 to 120 grains, or even more.

11. *Surface and Subsoil Water.*—Very variable in composition, but often very impure, and always to be regarded with suspicion. Heaths and moors, on primitive rocks, or hard millstone grit, may supply a pure water, which may, however, be sometimes slightly colored with vegetable matter. Cultivated lands, with rich manured soils, give a water containing often both organic matter and salts in large quantity. Some soils contain potassium, sodium, and magnesium nitrates, and give up these salts in large quantity to water. This is the case in several parts of India, at Aden, and at Nassick in the Deccan (Haines). In towns and among the habitations of men, the surface-water and the shallow well-water often contain large quantities of calcium and sodium nitrites, nitrates, sulphates, phosphates, and chlorides. The nitrates in this case probably arise from ammonia, ammonium nitrite being first formed, which dissolves large quantities of lime. Organic matter exists often in large amount, and slowly oxidizes, forming nitric acid and ammonia. In some cases butyric acid, which often unites with lime, is also formed.

12. *Marsh Water.*—This always contains a large amount of vegetable organic matter; it is not unusual to find from 12 to 40 grains, and in some cases even more. Suspended organic matter is also common. The salts are variable. A little calcium and sodium in combination with carbonic and sulphuric acids and chlorine are the most usual. Of course, if the marsh is a salt one, the mineral constituents of sea-water are present in varying proportions.

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[1] Sometimes the water drawn from the upper part of the chalk is really derived from tertiary sand lying above the chalk. The water contains less calcium carbonate, and more sodium carbonate and chloride, and may be alkaline.

13. *Water from Graveyards.*—Ammonium and calcium nitrites and nitrates, and sometimes fatty acids, and much organic matter. Lefort found a well of water at St. Didier, more than 330 feet from a cemetery, to be largely contaminated with ammoniacal salts and an organic matter which was left on evaporation. The water was clear at first, but had a vapid taste, and speedily became putrid.

14. *Artesian Well-Water.*—The composition varies greatly. In some cases the water is so highly charged with saline matter as to be undrinkable; the water of the Artesian well at Grenelle contains enough sodium and potassium carbonates to make it alkaline; there is also often a considerable amount of free or saline ammonia. In some cases the water contains an appreciable amount of iron; in other cases, especially when drawn from the lower part of the chalk, or the green sand below it, it is tolerably pure. Its temperature is usually high in proportion to the depth of the well. The aëration of the water is often moderate, sometimes *nil.* These last two points sometimes militate against the employment of water from very deep wells.

15. *Water from Wells near the Sea.*[1]—This frequently contains so much saline matter as to taste quite brackish, although the organic matter may not be very large. In some samples from Shoeburyness (analyzed at Netley) the total solids ranged from 104 to 218 grains per gallon of total solids, the chlorides being from 22 to 65: mean of six samples—165 total solids, and 35 of chlorides. In one sample, however, the albuminoid ammonia was only 0.07 per million, and in five the oxygen required for organic matter was under 0.75 per million. At Landguard Fort, water from a boring 150 feet deep yielded more than 500 grains of solids and 380 grains of chlorides.

16. *Rain-Water* may be contaminated by washing the air it falls through, but more by the surface on which it falls, such as decaying leaves, bird droppings, soot, or other matter on the roofs of houses; it also takes lead from lead coatings and pipes, and zinc from zinc roofs.

2. Impurities of Transit from Source to Reservoirs.

Open conduits are liable to be contaminated by surface washings carrying in finely divided clay, sand, chalk, and animal matters from cultivated land; and the leaves and branches of trees and their contingent of vegetable matters. These impurities may occur in most cases, but in addition the refuse of houses, trades, and factories is often poured into rivers, and all sorts of matters are thus added.

These impurities are broadly divided by the Rivers Pollution Commissioners into "sewage" and "manufacturing:" under the former term all solid and liquid excreta, house and waste water, and in fact all impurities coming from dwellings are included; under the latter term are placed all manufacturing refuse, such as from dye and bleach works, tanneries, paper-making, woollen, silk, and metal works, etc.[2]

The very numerous animal and vegetable substances derived from habitations are usually classed under the vague, but convenient term of "organic

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[1] For a good example of the influence of a tidal river on neighboring wells, see my Lectures on State Medicine, Table x., p. 91.—[F. de C.] On the other hand, springs situated near the sea have been found very pure.

[2] For a full account of all these impurities, and the best mode of dealing with them, the six Reports of the River Pollution Commissioners must be referred to.

matter," as the separation of the individual substances is impossible. The organic matter is usually nitrogenous, and Frankland has proposed to express its amount in terms of its nitrogen (organic nitrogen), but this view is not yet generally received on account of the difficulty of estimating the very small quantity of nitrogen. The nitrogenous organic matter undergoes gradual transformation, and forms ammonia, and nitrous and nitric acids. The exact steps of this process are perhaps complicated. On keeping the water the nitrites disappear, and in some cases the nitrates also gradually diminish, probably from the action of *bacteria*. A. Müller[1] found the residue of a well-water gave with sodium hydrate a herring-like odor, which seemed like trimethylamine.

Many of the "organic matters" in water are not actually dissolved, but are so finely suspended that they pass through filtering paper. There is no doubt that among this "suspended organic matter" many small plants and animals are always included. It is probably owing to the variation in the quantity of suspended organic matter (living and dead) that water from the same source sometimes gives different results on analysis, even though the water be taken at the same time. During its flow in open conduits, however, a species of purification goes on, by means of subsidence, the action of water-plants, and to some moderate extent by oxidation. On the whole these processes appear in India to render river-water, in spite of all the contaminations it receives, purer than tank and well-water.[2] The freedom from noxious substances is also apparently greater in India in the quick-running streams, which may also depend upon purification taking place in them.[3]

3. Impurities of Storage.

The chance of substances getting into the water of wells, and tanks,[4] and even of cisterns in houses, is very great. Surface washings and soakage contaminate wells and tanks, and leakages from pipes, passage of foul air through pipes, or direct absorption of air by an uncovered surface of water, introduce impurities into cisterns.[5] It is singular in how many ways cisterns and tank waters get foul, and what care is necessary not only to place the cistern under safe conditions at first, but to examine it from time to time to detect contamination of the water. In India, especially, the tank water is often contaminated by clothes washed near, or actually in, the tank; by the passage even of excrement directly into it, as well as by surface washings, so that in fact in some cases the village tank is one of

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[1] Roth and Lex, Militär-Gesundheitspfl., p. 16.

[2] Palmer shows this clearly in a very interesting paper in the Indian Medical Gazette for December, 1870.

[3] Much influence has been ascribed to oxidation, and doubtless in part correctly; but Dr. Frankland has shown its effect to be limited. The Irwell river, after passing Manchester, runs 11 miles to its junction with the Mersey without further material pollution, and falls over 6 weirs; yet the purification by oxidation is trifling. By siphoning water from one vessel to another so as to represent a run of 96 miles, the organic carbon was only reduced 6.4 per cent. and the organic nitrogen 28.4 per cent. This, however, is widely different from running in an open river bed.

[4] In two examples of (so called) rain-water collected in tanks in the marsh near Tilbury Fort for the use of the troops, the solids were found to be respectively 41 and 145 grains per gallon (Army Medical Reports, vol. xvii., p. 214).

[5] A good case of absorption by an open cistern of gases from water-closets and urinals is recorded by Druitt (Medical Times and Gazette, September, 1869). The water as supplied contains .08 part per million of albuminoid ammonia; after absorption, 17 parts.

the chief causes of the sickness of the people. There is, perhaps, no point on which the attention of the sanitary officer should be more constantly fixed than that of the storage of water, either on the large or small scale.

In shallow wells (4 to 30 feet deep) the soakage water from the ground in loose soils of chalk and sand is often very impure. Thus in a town the well-water often shows evidence of nitrites, nitrates, and ammonia, and chlorine far in excess of river-water in the neighborhood, though the strata are the same.[1] Occasionally, by constant passage of the water, a channel is formed, which may suddenly discharge into the well; and probably some of the cases of sudden poisoning from water have thus arisen.

A well drains an extent of ground about it nearly in the shape of an inverted cone. The area must depend on the soil; but the experiments at Grenelle and Passy show that the radius of the area drained is equal to four times the depth at least, and that it often exceeds this.[2] Professor Ansted states that the deepest (non-Artesian) well will not drain a cone which is more than half a mile in radius.

In some cases a well at lower level may receive the drainage of surrounding hills flowing down to it from great distances. Good coping stones, so as to protect from surface washings; good masonry for several feet below the surface of wells in very loose soils, so as to prevent superficial soakage, are necessary in all shallow wells.

4. Impurities of Distribution.

If water is distributed by hand, *i.e.*, by water-carts, barrels, or skins, there is necessarily a great chance of its being fouled. In India, where the water is generally carried by water-carriers (Bhisties), inspection of the carts or skins should be systematically made, and whenever it be possible, pipes should be substituted for the rude method of hand conveyance. But even pipes may contaminate water; metals (lead, zinc, and iron) may be partly dissolved; wood rots, and if the pipes are occasionally empty, impure air may be drawn into them, and be afterward absorbed by the water.[3] In towns supplied on the constant system, when the pipes are becoming empty the flow of water from a tap has drawn foul water or air through a pipe at some distance, and in this way even the water of the mains has been befouled.

Coal gas passing into the ground from leaking of gas-pipes sometimes finds its way into wells, or even into water-pipes. In Berlin, in 1864, out of 940 public wells, 39 were contaminated by admixture with coal gas. A good instance is related by Mr. Harvey,[4] where the main pipes were often empty and gas penetrated into them. Having regard to the cases in which gases from the soil (from leaking gas-pipes, sewers, etc.) find their way into water-pipes, it would seem important not to lay down water-pipes near any other, or, what is better, have all pipes in sub-ways where they can be inspected.

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[1] Roth and Lex, op. cit., p. 43.

[2] Études sur le mouvement des Eaux, par J. Dupuit.

[3] Cases of this sort are given in the Reports of the Medical Officer of the Privy Council, No. ii., new series. See Dr. Blaxall on Fever at Sherborne, Dorset, and Dr. Buchanan on the Fever at Caius College, Cambridge. In the latter case foul trap-water was sucked in from the closets. At Croydon, blood was sucked in this way from a butcher's shop.

[4] Food, Water, and Air, February, 1872, p. 68.

SECTION III.

PURIFICATION OF WATER.

Without Filtration.

1. *Exposure to Air in divided Currents.*—This was a plan proposed by Lind, for the water of the African west coast, more than one hundred years ago, and frequently revived since. The water is simply poured through a sieve, or a tin or wooden plate, pierced with many small holes, so as to cause it to fall in finely divided streams, or a hand-pump is inserted in a cask of water, and the water is pumped up, and made to fall through perforated sheets of tin. It soon removes hydrogen sulphide, offensive organic vapors, and, it is said, dissolved organic matter. The same plan has been used in Russia on a large scale, the water being allowed to fall down a series of steps, passing through wire gauze as it does so. In Paris, also, it has been employed on the small scale.

2. *Boiling and Agitation.*—This plan gets rid of calcium carbonate, iron in part, and hydrogen sulphide, and lessens, it is said, organic matter. It is uncertain if boiling will completely destroy the poisons of the specific diseases, but it is highly probable. It will not destroy completely all *bacteria*, or at least their germs still live, and Lex found some *bacteria*, still moving rapidly, at a temperature of 127° C.[1] Tyndall's experiments have shown that there are stages in the life of *bacteria* during which they can resist almost any moist heat. But as they soften before propagation a solution can be successfully sterilized by repeated boilings, so as to attack the several crops of *bacteria* in their vulnerable condition. Most *fungus* spores are killed by boiling.

3. *Aluminous Salts.*—Alum has been used for centuries in India and China, to purify water from suspended matters. It does this very effectually, if there be calcium carbonate in the water; calcium sulphate is formed, and this and a bulky aluminium hydrate entangle the floating particles and sink to the bottom. Mr. Alfred Bird has proposed aluminium tersulphate, which is equally efficacious; it is an acid liquid, containing about .4 grain of the sulphate in each minim; and M. Bellamy[2] has also proposed a modification of the alum process, by adding additional potash to a solution of alum till the precipitate is redissolved. The quantity of crystallized alum to be used should be about six grains per gallon; of Mr. Bird's fluid (sulphate of alumina), twenty drops.

From numerous experiments on purification with crystallized alum, and with Mr. Bird's patent liquid, with and without calcium carbonate in the water, it is clear not only that calcium carbonate ought to be in the water, but that the action of both alum and Bird's fluid is made more upon the suspended organic matters than upon those actually dissolved; and, indeed, having regard to the great difficulty of insuring that water is actually free from minute suspended matters, it is even a question whether aluminous salts will act in any appreciable degree on dissolved organic matters. But on suspended matters, both organic and mineral, the effect

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[1] Sanderson puts the death-point of common septic *bacteria* at about 110° C. or 230° F.

[2] Comptes Rendus de l'Acad., November 11, 1867, p. 799.

is very great indeed. Common alum and Bird's liquid seem practically equal; but alum, being solid, is more convenient for transport.[1]

If a sedimentous water is extremely soft, a little calcium chloride and sodium carbonate should be put in before the alum is added.

4. *Addition of Lime Water* (Clark's patent).—By combining with carbonic acid, it causes almost all the calcium carbonate previously and newly formed to be thrown down. It also throws down suspended and a certain proportion of dissolved organic matters, and also, it is said, iron. It does not touch calcium and magnesium sulphate and chloride.[2]

5. *Sodium Carbonate*, with boiling, throws down lime, and possibly a little lead, if present.

6. *Addition of Potassium or Sodium Permanganate* (Condy's red fluid). —Pure Condy's fluid readily removes the smell of hydrogen sulphide and the peculiar offensive odor of impure water which has been kept in casks or tanks. If it forms a precipitate of manganic oxide, it also carries down suspended matters; but the formation of this precipitate is very uncertain. The action on the dissolved organic matters will, of course, vary with the nature of the substance; some of the organic matters, both animal and vegetable, will be oxidized; but in the cold it will not act upon the whole of these substances, and some organic matters are not touched.

One objection to the use of the permanganate is that it often communicates a yellow tint to the water, arising from suspended finely divided peroxide of manganese. This is probably of no moment as far as health is concerned, but it is unpleasant. Sometimes the addition of a little alum will carry down this suspended matter; boiling may be used but often has no effect. Sometimes nothing removes it but filtration.

The indications for the use of permanganate are these. In the case of any foul-smelling or suspected water, add good Condy's fluid, teaspoonful by teaspoonful, to 3 or 4 gallons of the water, stirring constantly. When the least permanent pink tint is perceptible, stop for five minutes; if the tint is gone, add 36 drops, and then, if necessary, 30 more, and then allow to stand for six hours; then add for each gallon 6 grains of a solution of crystallized alum, and if the water is very soft, a little calcium chloride and sodium carbonate, and allow to stand for twelve or eighteen hours.

There are many cases in which this plan may be useful; and as the permanganate certainly removes smells and oxidizes in the cold to some extent, it is a very good introduction to the alum process, and does work which alum alone will not do. But it cannot be considered a complete purifier of water from all organic matters. Its oxidizing power is, however, often useful in cleaning charcoal filters, as will be presently noted.

7. *Perchloride of Iron.*—It has been found that the water of the Maas in Holland, which is turbid from clay and finely suspended organic matters, and gives rise in consequence to diarrhœa, is completely purified by perchloride of iron in the proportion of about $2\frac{1}{2}$ grains of the solid perchloride to 1 gallon of water.[3] It is a powerful oxidizing agent.

Use of the Strychnos potatorum.—In India the fruit of the *Strychnos potatorum* is used, especially by the better class of Hindoos, to purify water.

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[1] The headquarter wing of the 92d Highlanders, going up the Indus in 1868, suffered from diarrhœa from the use of the water; the left wing used alum, and had no diarrhœa. The right wing then used it, and the diarrhœa disappeared.—*Indian Medical Gazette*, August, 1869, p. 158.

[2] This plan has been carried out with great success on a large scale, in the form known as the Porter-Clark process, and also in a modified form by Messrs. Atkins.

[3] Chemical News, May, 1869, p. 239.

It is beaten into a paste, and rubbed on the inside of the water jar or cask. Dr. Mouat says that it is chiefly used for the river-water at the seasons when it is laden with silt, and that about 30 grains are used for 100 gallons of water, which act in twenty-four hours. Its action appears to be on suspended matters, which it possibly carries down by giving to the water a delicate albuminous coagulum, so that it purifies water on the same principle as beer is fined.[1] Dr. O'Shaughnessy thought its action was connected with its astringency. Some experiments on its action were made at Netley, but without any satisfactory result. It did not even clear the water thoroughly from suspended matters, and it had no effect on the amount of nitrous acid, ammonia, or of oxidizable organic matters, as far as these could be judged of by potassium permanganate. Renewed experiments are, however, necessary.

8. *Immersion of Iron Wire and Magnetic Oxide of Iron* (Medlock).—This plan is said to decompose organic matter. Charcoal and ferric oxide are sometimes mixed.

9. *Immersion or boiling of certain Vegetables*, especially those containing tannin, such as tea,[2] kino, the Laurier rose (*Nerium Oleander*, which is also rubbed on the inside of casks in Barbary), bitter almonds (in Egypt).

10. *Charring the inside of Casks.*—This is an effectual plan, and Berthollet considered it more effectual than the immersion of pieces of charcoal; the charring can be renewed from time to time.

To put these facts in another form:—

Organic matter is got rid of most readily by exposure to air, boiling, agitation, charcoal, alum, potassium permanganate, astringents.

Carbonate of Lime by boiling and addition of caustic lime.

Iron, by boiling and lime water, and in part by charcoal.[3]

Calcium and magnesium sulphate and chloride cannot be got rid of.

It should be remembered that some water-plants have a purifying effect, apparently from the large quantity of oxygen they give out; and this takes place sometimes though the water itself is green.

With Filtration.

Sand and Gravel.—On the large scale, water is received into settling reservoirs, where the most bulky substances subside, and is then filtered through gravel and sand, either by descent or ascent, or both.[4]

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[1] Pereira, Pharmaceutical Journal, vol. ix., p. 478.

[2] In the north of China, and especially during winter, the water of the Peiho becomes very impure, and contains not only suspended matters, but dissolved animal matter in large quantity, which gives the water a disagreeable offensive smell. The Chinese never drink it except as tea, which is cooled with a lump of ice, if it is desired to drink it cold. In this way they secure themselves from all bad effects of this water (Friedel, Das Klima Ost-Asiens, p. 60). The Europeans use alum and charcoal; but these do not always entirely remove the taste. The Tartars also use their "brick tea" to purify the water of the steppes, which would otherwise be undrinkable.

[3] Chevalier, Traité des Désinfect., p. 147. In the Ashanti campaign, under the directions of Surgeon-Major V. Gouldsbury, C.M.G., the water was purified in the following way, in the absence of proper filters:—Alum was added to precipitate suspended matter—the water was passed through a rough filter, consisting of (1) sponge; (2) sand; (3) charcoal in pieces; it was then boiled, and a few drops of solution of potassium permanganate added. Water, even taken from a hole in a marsh, was innocuous after this treatment.

[4] A good account of the engineering plans and filtration of the London Water Companies will be found in a work called The Water Works of London, by Messrs. Colburn & Shaw, 1867.

The London water companies usually employ a depth of 3 to 5 feet ; in the latter case, the upper stratum of 18 inches or 2 feet is composed of sand, the lower 3 feet are made up of gravel, gradually increasing in coarseness, from pieces the size of a small pea and bean to that of a middle-sized potato. A stratum of oyster shells, about $1\frac{1}{2}$ inch in thickness, has been used by some companies instead of a layer of gravel ; but this plan is not general. If the filter is 3 feet in thickness, the upper 15 inches are sand, and the lower 21 inches are gravel.

The pressure of water in these filters is not great ; the depth of the water is never above 2 feet, and some companies have only 1 foot. From 70 to 75 gallons is the usual quantity which should pass through in twenty-four hours for each square foot ; but some companies filter more quickly, viz., at the rate of a gallon per twenty-four hours for each square inch, or 144 gallons per square foot.

The sand should not be too fine ; the sharp angular particles are the best. The action seems chiefly, perhaps altogether, mechanical ; the suspended impurities, both mineral and organic, rub upon and adhere to the angles and plane surfaces of the sand, which are gradually encrusted, and after a certain time the sand has to be cleaned. The effect on suspended matters, both organic and mineral, is certainly satisfactory. On dissolved organic matter it is less so.[1] Mr. Witt's experiments show only a removal of about 5 per cent.

Some experiments were made at Netley on a sand filter of 1 square foot surface, and made in imitation of a London water company's filter, viz., 15 inches of fine, well-washed white sand, and $20\frac{1}{2}$ inches of gravel, gradually increasing in coarseness. The first eight gallons were thrown away, so as to avoid the fallacy of including the distilled water with which the sand had been washed.

This sand filter had some effect in lessening the dissolved constituents, both mineral and organic, but the effect was limited ; it stopped organic matter after it had ceased to arrest lime. After a longer time it became useless, and required washing.

It is yet uncertain whether the action of sand on organic matter is at all chemical, *i.e.*, whether the organic matter is oxidized in its transit ; considering what an amount of air is contained in the interstices of sand, and how finely the water is divided in its transit, some amount of oxidation is probable, but good chemical evidence is yet wanted. Mr. Shield's experiments, given in the note, seem opposed to the probability of much chemical action. On dissolved mineral matters sand exerts at first, and when in thick layers, a good deal of action ; much sodium chloride can be removed ; and Professor Clark has stated that even lead can be got rid of by filtering through a thick stratum. Very finely divided clay seems to pass through more readily than any other suspended matters.[2]

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[1] In a sand and gravel filter, 33 inches in thickness, Mr. Shield (Proc. Inst. of Civil Engineers for 1867) gives the following numbers :—The original amount of organic matter being .8906 grain per gallon, the amount after filtration was as follows —after 23 hours action, 1.102 ; after 120 hours, .648 ; after 240 hours, .917 ; after 376 hours, .809. So that, while on the whole, the sand removed some organic matter, the amount is really inconsiderable.

[2] A peculiar difficulty, never experienced in England, has been discovered in the filtering, through sand, of the Hooghly water at Calcutta ; during the rainy season the fine mud brought down penetrates very deeply into the filters, and rapidly chokes them ; in the dry season this does not happen ; the suspended matters are arrested, as in England, near the upper surface of the sand. Mr. D. Waldie (Journal of the Asiatic Society of Bengal for 1873, part 11, p. 210) explains this by showing that in the

The fine white sand is the best; it should be chosen carefully, and well washed, and, if possible, heated to redness before use.

Instead of sand and gravel, trap-rock has been used.

Sponge.—Sponge has a considerable effect in mechanically arresting suspended particles, but very little on dissolved matters.

Animal Charcoal.—Pure animal charcoal (deprived, as far as possible, of calcium phosphate and carbonate by washing or by hydrochloric acid) used to be considered one of the best filtering materials. The particles of charcoal should be well pressed together, and the passage of the water should not be too quick. Contact with the water for about four minutes appears sufficient. There is a large (and, if the layer of charcoal be deep enough, complete) removal of suspended matters, both mineral and organic; water even deeply tinged comes through a good charcoal filter very clear and bright. So also dissolved organic and mineral matters are removed by charcoal in the first instance. All evidence agrees in respect of that point. But then its power is limited, and after a time it ceases to be efficient.

In experiments made with animal charcoal at Netley (by Drs. F. de Chaumont and J. L. Notter) it was found that it had a very rapid and powerful effect upon dead or decomposing organic matter, but that it allowed fresh organic matter, such as fresh egg albumen, to pass through to a large extent unchanged.[1] This suggests serious considerations with reference to the effect upon disease poisons. It was also found (as in Mr. Byrne's experiments) that after a time the filtering action not only ceased, but that the charcoal began to give back some of the organic matter it had removed. The same result takes place if the water be left too long in contact with the charcoal. Water filtered through charcoal, if it be kept for any length of time, shows some evidence of low forms of organic life—in some instances a copious deposit forming. This may be due either to spores or germs passing through unchanged,[2] or to the phosphates yielded by the charcoal affording a favorable nutrient for germs absorbed from the atmosphere. For these reasons it seems unadvisable to use charcoal for filtration on a large scale, independent of the consideration of expense. The plan of placing charcoal filters in water cisterns, now often practised, ought also to be given up. The conclusions to be arrived at with regard to charcoal as a filtering medium are these:—(1) It acts both chemically and mechanically, and is at first both rapid and efficient. (2) With a good bulk of material, water may be passed through nearly as rapidly as it can flow and be well purified. (3) Water must not be left in contact with the charcoal longer than is necessary for filtration, as it is apt to take up organic matter again. (4) Water filtered through charcoal must not be stored for any time, but must be used immediately, as if kept it is apt to become

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rainy season the water contains much less saline matter than in the dry season; it is this saline matter which seems to act on and so cause coherence of the particles of mud, so that they become larger and coarser, and are more easily arrested. In order to remedy this, Mr. Waldie proposes the addition of substances to the water during the rains, which may cause this coalescence; he has tried a great number of experiments and different substances, on the whole crystallized alum and perchloride of iron are the best; 55.4 ℔. of crystallized alum, or 19.15 ℔. of perchloride of iron, were found to be necessary for the clarification of one million gallons of muddy Hooghly water during the rainy season.

[1] See Sanitary Record, Oct., 1876, p. 288, and A. M. D. Reports, vol. xix, p. 170.

[2] This appears the more probable. Minute diatoms were found in water which had been kept for some months that had passed through Crease's large filter tanks at Parkhurst.

charged with minute living organisms. (5) Since fresh organic matter may pass through it unchanged, animal charcoal cannot be confidently depended upon to purify water from disease poisons. (6) The power of charcoal is limited; with a moderately good water it remains efficient for some time, but with an impure water it soon becomes inactive. In most cases it ought to be cleaned or renewed every three months.

Vegetable Charcoal—Peat Charcoal—Seaweed Charcoal.—The first is much less efficacious than animal charcoal—even useless according to Frankland. The others are rather more effectual, but do not appear to be very powerful; they should only be used when animal charcoal cannot be obtained.

Spongy Iron.—This substance, obtained by roasting hæmatite iron ore, is porous metallic iron, and not unlike animal charcoal in appearance. It occupies a space of about twenty cubic feet to the ton. Its action on water is both mechanical and chemical, for it arrests suspended matter and also oxidizes organic matter in solution. It acts upon water itself, decomposing it and setting free hydrogen—the oxygen being afterward given up to organic matter that may come in contact with it. Its oxidizing power is very great, although perhaps a little slow. Experiments at Netley [1] showed that it could be depended upon to remove the greater part of the dissolved organic matter, and with prolonged exposure the whole of it in many instances. It has not much effect on mineral matter, but removes lead. It yields a little iron to the water, which, however, can be removed by further filtration through prepared sand—that is, sand or fine gravel with pyrolusite. Beyond this nothing is yielded to the water, which comes out quite clear and pure, and may be stored for a long time without undergoing any change or showing signs of the production of living organisms —or in any way favoring putrefaction.[2] Water left in contact with it does not deteriorate. It retains its filtering power a long time, very much longer than animal charcoal. Those properties render it suitable for use on a large scale, and it has been so used in several places; as, for example, in the Water Works of Antwerp. On the whole, it must be looked upon as one of the most powerful and lasting filtering media we have.

Carferal.—This substance has been introduced within the last two or three years. It is a black granular matter, bearing an external resemblance to granular animal charcoal. Its specific gravity is 2.879, and its bulk in its usual condition is about 25 cubic feet to the ton. Its method of manufacture and composition have not as yet been made known, so far as can be ascertained—but it consists of a mixture of charcoal and iron in small quantities with a basis of clay.[3] It has very considerable purifying powers, and acts very rapidly, even upon fresh albumin, yielding nothing deleterious to the water, which may be stored for a time without the production of any organisms. Its lasting powers appear to be slightly better than those of the animal charcoal, although inferior to those of spongy iron.[4] There is, however, the objection that it appears to have no definite composition. It is also probable that there is more than one sort in the market, or that the material is adulterated from time to time, a thing difficult to detect when the original composition is uncertain.

Domestic Filters.—On a small scale, a number of substances have been

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[1] A M D. Reports, vol. xx., p. 205 et seq.

[2] See M. Gustav Bischof, "On Putrescent Organic Matter in Potable Water," Proc. Royal Soc., No. 80, 1877; also "Sanitary Notes on Potable Water," Sanitary Record, vol. x., p. 337

[3] Hence the name "Carferal," from the first syllables of *Car*bon, *fer*rum, and *al*umina.

[4] See A.M.D. Reports, vol. xx., p. 205 et seq., and vol. xxi., p. 228.

used, such as animal and vegetable charcoal, in granules or powder, or made into blocks, or fine silica impregnated with charcoal (silicated carbon filters), hæmatite and magnetic iron ores, the so-called magnetic carbide, spongy iron, manganic oxide, flannel, wool, sponges, porous sandstones (natural and artificial), etc.

The Souchon filters, which are much employed in Paris, are made of diaphragms of wool, which is partially tanned by boiling in solution of alum and cream of tartar, then dyeing in infusion of gall-nuts, and washing in solution of sodium carbonate. The filter of M. Fonvielle, also used in Paris, is composed of nine layers of sponges, pounded sandstone, and gravel.

The "Filtre Rapide" of Maignen is an ingenious arrangement, by which a large straining surface is presented to the water by the spreading of asbestos cloth over a frame, or over a perforated cone of porcelain. Any filtering medium in powder or granules may be mixed with the water and settles on the cloth; this, of course, can be renewed as required.

The "Filtre Chanoit" is much used in France. The straining material is ground slag ("Scorie de fonte"), and the filter requires to be used under pressure (5 centimeters); by this means a cushion of air is compressed, and acts as a purifier.

The filters in the market in this country are very numerous, but the most important are the following:—

1. Those containing animal charcoal, in granules or powder.
2. Animal charcoal compressed into blocks by admixture with silica and other substances.
3. Spongy iron filters.
4. Those containing carferal and other substances of a nature chiefly mineral.

The essentials of a good filter are the following:—

1. That every part of the filter shall be easily got at, for the purposes of cleaning, or of renewing the medium.
2. That the medium have a sufficiently purifying power, and be present in sufficient quantity.
3. That the medium yield nothing to the water that may favor the growth of low forms of life.
4. That the purifying power be reasonably lasting.
5. That there shall be nothing in the construction of the filter itself that shall be capable of undergoing putrefaction, or of yielding metallic or other impurities to the water.
6. That the filtering material shall not be able to clog, and that the delivery of the water shall be reasonably rapid.

The *first* of these conditions obviously sets aside all filters of the older, and what used to be the usual, pattern, where only a small layer of filtering material was present, which was cemented up so as not to be reached without breaking open the apparatus.

The *second* condition is fulfilled, so far as filtering power is concerned, by a number of media; with regard to bulk of material this is also fairly well attended to in the filters when loose material is used—but where solid blocks are employed the size is often quite incommensurate with the work they are called upon to do.

The *third* condition is complied with by spongy iron, good samples of carferal, and some other materials—but (as before mentioned) not by

animal charcoal in the loose condition. As solid blocks, it seems to yield less to water than in the granular condition.

The *fourth* condition depends a good deal upon the relative degree of impurity of the water. The spongy iron on the whole lasts the longest.

The *fifth* condition demands that nothing organic shall be used in the construction of the filter, or in the packing of the interior.[1] Iron or other metal must be protected from the action of the water.[2]

The *sixth* condition is generally fulfilled when the material is loose and when the water is not too full of suspended matter. Sometimes sponge is used to arrest suspended matter, but it is so apt to get foul that its use had better be avoided. The block filters are very apt to clog, a slimy substance forming on their surface. This is partly obviated now by the use of asbestos strainers (as in the silicated carbon filter). Spongy iron is apt to cake unless kept constantly covered with water, but this is arranged for in the new forms of filter. As regards rapidity of delivery, the animal charcoal and the carferal (when the sample is really good) have the advantage over spongy iron and block filters—in the following ratio:—

1. Animal Charcoal, } Water runs through fairly well purified in
2. Carferal, } 2½ to 4 minutes.
3. Silicated Carbon, Average exposure, 15 minutes.
4. Spongy Iron,[3] " " 22 "

It is obvious that, for reasons of convenience, one filter may be preferable to the others according to circumstances. If the water is required immediately in considerable quantity, and is to be consumed at once, either animal charcoal or carferal would be used. In the other cases, where the delivery is slower, the size or the number of the filters would have to be arranged accordingly.

Cleansing of Filters.—All filters when first taken into use require to be washed by passing from ten to twenty gallons of fairly good water through them, according to the size of the filter, as the filtering medium generally yields something to water in the beginning. It is also necessary to ensure the removal of dust, etc., that may be in the apparatus. But after a certain time of use all filtering media not only cease to be efficient, but even in some instances give up impurity to the water passed through them; so much is this the fact that cases of illness have been traced to this source, and some persons have thought the dangers of filtration were greater than those of unfiltered water. There is no doubt that the practice of depending for years upon the efficiency of a filter, which has never been cleaned or had its material renewed, is fraught with danger, and there is still danger to be apprehended from many of the so-called "self-cleaning" filters which, in the words of the advertisement, "require no attention." There is a limit to the power of all filtering materials, and no implicit confidence can be placed in any of the methods vaunted as "self-cleaning." It is not possible to state positively the length of time any filtering material will remain efficient, so much depending upon the condition of the water and the quantity passed through. *Animal charcoal* in granules or powder ought to be examined at least every three months. If water

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[1] Cotton has sometimes been used and gone rapidly to decay.

[2] Water has been found strongly charged with zinc, from the use of so-called galvanized iron in filters.

[3] Water can be drawn off much more rapidly from this filter, if required, but this is not recommended by the inventor.

passed through it can be chemically and microscopically analyzed and is found pure, the charcoal may be continued in use—but in the absence of such assurance it will be safer to take steps for cleaning it. The best plan of all is to heat it to redness under cover, and then wash it with distilled water or the cleanest that can be procured. Failing this, boiling it, with or without permanganate of potassium solution or dilute Condy's fluid and a little mineral acid, is the safest plan. After this it may be exposed to the air and sun, thoroughly washed, and then used again. The permanganate solution (or Condy's fluid) should be passed through it until it comes out a distinct pink color. *Carferal* may be treated in much the same way as charcoal, with the omission of the permanganate solution ; but it must be remembered that in both cases the duration of efficiency depends greatly upon the bulk of the material with reference to the quantity of water passed through it.

Spongy iron retains its efficiency for a long time, and, as in the filters made with it the flow of water is expressly limited with reference to the bulk of material, the difference is solely in relation to the greater or less impurity of the water acted upon. Its efficiency may generally be depended upon for a year, and unless the water be very impure, even for a considerably longer time. So long as the water filtered through it appears chemically and microscopically pure, the filtration may be carried on with confidence. When the limit of efficiency is reached, the only safe plan is to renew the charge of material, and it is generally advisable to provide for this renewal once a year ; should circumstances arise, however, to prevent this renewal, the best plan for cleaning is to subject all the material to the action of fire, up to a low red heat, then to wash the whole well, and return it into the filter. The cleansing with permanganate and acid *must not* be attempted.

Filters, where the material is cemented up and cannot be removed, ought to be abandoned altogether.

Strainers of sponge, or any material which cannot stand the action of fire, ought also to be given up. Asbestos forms an excellent strainer, and can be heated to redness, so as to destroy all organic matter, as often as required.

Block Filters are generally undesirable forms ; but if used, they may be cleansed by carefully brushing the surface, pumping air in the reverse way, and treating with permanganate as above described. They are of various sizes, from small pocket filters to large-sized domestic filters delivering thirty to fifty gallons a day. The pocket filters are useful as strainers, but their small size must make the duration of their oxidizing power very short. They ought to be frequently brushed and washed in clean water, with permanganate if possible.

Cistern and Pipe Filters.—Filters are sometimes placed in cisterns, being constantly immersed in the water to be filtered. This is an objectionable plan, and ought to be abandoned. Pipe filters are those which are placed in the course of a supply pipe, and tap-filters those which are fitted on to a delivery tap. The objection to most of those filters is that they are generally much too small for the work expected from them, as they are usually represented by a small cylinder of block carbon or a few ounces of animal charcoal. For proper filtration the only way is to have a full-sized filter attached to the supply pipe, with a ball-cock or similar apparatus for filling it.[1] The object is of course twofold—first, to ensure

[1] See Fig. 11, p. 110.

that all the water drawn shall be filtered, and, second, to save the time required when the filter has to be filled by hand.

Service Filters for Land and Sea.—Lieut.-Col. Crease, C.B., Royal Marine Artillery, has arranged some excellent forms of filters, both small for barrack, hospital, or ambulance use, and large tanks for ships, or for large bodies of men on shore. The principle of them all is a filter of strong durable material, which yields nothing to water, space for a large quantity of filtering material, and a rapid delivery. The small filters may be earthenware or iron, the latter being protected internally by a patent cement; the larger tanks are of iron, protected in the same way. The material originally used was sand and animal charcoal in separate compartments. This answered very well, and was reported upon very favorably by Surgeon-General Sir A. D. Home, K.C.B., V.C., in the Ashanti War.[1]

Carferal is now employed, so that the whole bulk is active filtering material. By using a large quantity of the material with a rapid delivery, a storage reservoir becomes unnecessary. The delivery can be regulated by screwing down or loosening a plate in the filter, so as to compress the material, or slacken the pressure as required.

SECTION IV.

EFFECTS OF AN INSUFFICIENT OR IMPURE SUPPLY OF WATER.

Sub-Section I.—Insufficient Supply.

The consequences either of a short supply of water for domestic purposes, or of difficulty in removing water which has been used, are very similar. On this point much valuable information was collected by the Health of Towns Commission in their invaluable Reports.[2] It was then shown that want of water leads to impurities of all kinds; the person and clothes are not washed, or are washed repeatedly in the same water; cooking water is used scantily, or more than once; habitations become dirty, streets are not cleaned, sewers become clogged; and in these various ways a want of water produces uncleanliness of the very air itself.

The result of such a state of things is a general lowered state of health among the population; it has been thought also that some skin diseases—scabies, and the epiphytic affections especially—and ophthalmia in some cases, are thus propagated. It also appears likely that the remarkable cessation of spotted typhus among the civilized and cleanly nations is in part owing, not merely to better ventilation, but to more frequent and thorough washing of clothes.

The deficiency of water leading to insufficient cleansing of sewers has a great effect on the spread of typhoid and of choleraic diarrhœa; and cases have been known in which outbreaks of the latter disease have been arrested by a heavy fall of rain.

Little is known with certainty of the effects produced on men by deficiency in the supply of water. Under ordinary circumstances, the sensation of thirst, the most delicate and imperative of all our feelings, never permits any great deficiency for a long time, and the water-removing

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[1] A. M. D. Reports, vol. xv., p. 247.

[2] First and Second Reports (with evidence) of the Health of Towns Commission, 1844 and 1845.

organs eliminate with wonderful rapidity any excess that may be taken, so as to keep the amount in the body within certain limits. But when circumstances prevent the supply of water, it is well known that the wish to drink becomes so great, that men will run any danger, or undergo any pain, in order to satisfy it. The exact bodily condition thus produced is not precisely known, but from experiments on animals and men, it would appear that a lessened amount of water in the body diminishes [1] the elimination of the pulmonary carbonic acid, the intestinal excreta, and all the important urinary excreta.

The more obvious effects produced on men who are deprived for some time of water is, besides the feeling of the most painful thirst, a great lowering of muscular strength and mental vigor. After a time exertion becomes almost impossible, and it is wonderful to see what an extraordinary change is produced in an amazingly short time if water can be then procured. The supply of water becomes, then, a matter of the most urgent necessity when men are undergoing great muscular efforts, and it is very important that the supply should be by small quantities of water being frequently taken, and not by a large amount at any one time. The restriction of water by trainers is based on a misapprehension : a little water, and often, should be the rule.

Sub-Section II.—Impure Supply.

At present, owing probably to the difficulty of making analyses of waters, the exact connection between impure water and disease does not stand on so precise an experimental basis as might be wished. There are some persons who have denied that even considerable organic or mineral impurity can be proved to produce any bad effect ; while others have believed that some mineral ingredients, such as calcium carbonate, are useful.

It may be true that water containing a large quantity of organic matter, or much calcium and magnesium sulphate, has been used for long periods without any ill effects. The water of the Canal de l'Ourcq, which contains much calcium bicarbonate and some calcium and magnesium sulphate, was found by Parent-Duchâtelet to produce no bad effect, and Boudet more recently asserted the same thing.[2]

In some of these cases, however, very little careful inquiry has been made into the state of health of those using the water, and that most fallacious of all evidence, a general impression, without a careful collection of facts, has often been the only ground on which the opinion has been come to. As well observed by Mr. Simon, in one of his philosophical Reports,[3] we cannot expect to find the effect of impure water always sudden and violent ; its results are indeed often gradual, and may elude ordinary observation, yet be not the less real and appreciable by a close inquiry. In fact, it is only when striking and violent effects are produced that public attention is arrested ; the minor and more insidious, but not less certain, evils are borne with the indifference and apathy of custom. In some cases it is by no means improbable that the use of the impure water, which is supposed

[1] The experiments of Falck and Scheffer on animals, and of Mosler on men and women, are here referred to.

[2] The Canal de l'Ourcq (which has a boat population of about 40,000) is now abandoned as a source of drinking water, and the greater part of Paris is supplied from the rivers Vanne and Seine.

[3] Second Annual Report to the City of London, p. 121.

to be innocuous, has been really restricted, or that experience has shown the necessity of purification in some way. This much seems to be certain, that as precise investigations proceed, and, indeed, in proportion to the care of the inquiry and the accuracy of the examination, a continually increasing class of cases is found to be connected with the use of impure water, and it seems only reasonable to infer that a still more rigid inquiry will further prove the frequency and importance of this mode of origin of some diseases.

Animal organic matter, especially when of fæcal origin ; vegetable organic matter, when derived from marshes ; and some salts and metals are the principal noxious ingredients.

Of the hurtful substances the suspended animal, and especially fæcal matters, are probably the worst. At least, it is remarkable how frequently, both in outbreaks of diarrhœa and typhoid fever, the reports notice turbidity, discoloration, and smell of the water. It is this fact which makes the examination of color and turbidity important. The thoroughly dissolved organic matters appear less hurtful ; at least there is some evidence that perfectly clear waters, though containing much matter dissipated by heat, and consisting of dissolved organic matter or its derivatives, are often taken without injury. Probably, also, the more recent the fæcal contamination, the more injurious, since the most poisonous attacks on record have been in cases of wells into which, after slow percolation for some time, a sudden gush of sewage water has taken place.

It has been frequently stated that the readily oxidizable organic matters in water are the most dangerous. This opinion has probably arisen from the idea that a substance in rapid chemical change is more likely to excite some corresponding and hurtful action in the body ; and it may be true, but there is no existing evidence which can be trusted on the point. There is, on the other hand, some evidence that animal matters forming fatty acids give rise to salts which, though not oxidizing into nitrous and nitric acid, are as hurtful as the more oxidizable substances.

Of late years, too, an opinion has been expressed that the amount of the mineral substances is of little consequence. This can be true only in a limited sense ; there are some mineral substances, such as sodium chloride or carbonate, or calcium carbonate, which, within certain limits, appear to do no harm. But in the case of other minerals, such as calcium and magnesium sulphates and chlorides, and calcium nitrate, there can be little doubt that their use is injurious to many persons. It seems also probable that a combination of impurities, and especially the coexistence of organic matter and calcium sulphate, is hurtful ; at least the analysis of waters which have decidedly produced injury often shows that the impurities have been numerous.

As far as at present known, the existence of *infusoria* of different kinds is not hurtful, though they may indicate by their abundance the presence of organic impurity. The effect of microzymes, *algæ*, or *fungi*, in drinking water is also a matter of which little or nothing is known, though it is very probable that future research may bring out something important in this direction.

The most practical way of stating the facts connected with the production of disease by water will be to enumerate the diseases which have been traced to the use of impure water, and to state the nature of the impurities.

1. AFFECTIONS OF THE ALIMENTARY MUCOUS MEMBRANE.

It is reasonable to suppose that the impurities of water would be likely to produce their greatest effect upon the membrane with which they come first in contact. This is in fact found to be the case.

Affections of the Stomach—Dyspepsia.

Symptoms which may be referred to the convenient term dyspepsia, and which consist in some loss of appetite, vague uneasiness or actual pain at the epigastrium, and slight nausea and constipation, with occasional diarrhœa, are caused by water containing a large quantity of calcium sulphate and chloride, and the magnesian salts. Dr. Sutherland found the hard water of the red sandstone rocks, which was formerly much used in Liverpool, to have a decided effect in producing constipation, lessening the secretions, and causing visceral obstructions; and in Glasgow, the substitution of soft for hard water lessened, according to Dr. Leech, the prevalence of dyspeptic complaints. It is a well-known fact that grooms object to give hard water to their horses, on the ground that it makes the coat staring and rough—a result which has been attributed to some derangement of digestion. The exact amount which will produce these symptoms has not been determined, but water containing more than 8 grains of each substance individually or collectively appears to be injurious to many persons. This would correspond to about 10 degrees of permanent hardness. A much less degree than this will affect some persons. In a well water at Chatham, which was found to disagree with so many persons that no one would use the water, the main ingredients were 19 grains of carbonate of lime, 11 grains of calcium sulphate, and 13 grains of sodium chloride per gallon. The total solids were 50 grains per gallon. In another case of the same kind, the total solids were 58 grains per gallon, the calcium carbonate was 22, the calcium sulphate 11, and the sodium chloride 14 grains per gallon.

Iron, in quantities sufficient to give a slight chalybeate taste, often produces slight dyspepsia, constipation, headache, and general malaise. Custom sometimes partly removes these effects.

Diarrhœa.

Many conditions produce diarrhœa.

(*a*) *Suspended Mineral Substances.*—Clay, Marl—as in the cases of the water of the Maas, the Mississippi, the Missouri, Rio Grande, Kansas,[1] of the Ganges, and many other rivers—will at certain times of the year produce diarrhœa, especially in persons unaccustomed to the water. The hill diarrhœa at Dhurmsala is produced, apparently, by suspended very fine scales of mica.[2]

(*b*) *Suspended Animal, and especially Fæcal Matters*, have produced diarrhœa in many cases; such water always contains dissolved organic matters, to which the effect may be partly owing. The case of Croydon in 1854 (Carpenter) is one of the most striking on record. In cases in which the water is largely contaminated with suspended sewage, it is im-

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[1] Hammond's Hygiene, p. 218.

[2] Whitwell, *vide* Dr. Macnamara's 8th Report on Potable Waters in Bengal, Appendix, p. 44.

portant to observe that the symptoms are often markedly choleraic (purging, vomiting, cramps, and even some loss of heat). This point has been again noticed by Oldekop of Astrachan,[1] who found marked choleraic symptoms to be produced by the water of the Volga, which is impregnated with sewage. Seven cases in one house of violent gastro-intestinal derangement (vomiting, diarrhœa, colic, and fever), produced by water contaminated by sewage which had passed into the cistern, are recorded by Dr. Gibb.[2] In the prison at Halle an outbreak of diarrhœa was traced by Dolbruck to the contamination of water with putrid substances. In St. Petersburg the water of the Neva, which is rich in organic substances, give diarrhœa to strangers.[3]

Suspended animal and vegetable substances, washed off the ground by heavy rain into shallow wells, have often produced diarrhœa, as at Prague in 1860, when an endemic of "catarrh of the alimentary canal" was caused by heavy floods washing impurities into wells.[4]

(*c*) *Suspended Vegetable Substances.*—In this country, and also in the late American civil war, several instances have occurred of diarrhœa arising from the use of surface and ditch water, which ceased when wells were sunk; possibly there might be also animal contamination. It is not, therefore, quite certain that suspended vegetable matter was the *vera causa.* Surgeon-Major Gore has recorded a violent outbreak of diarrhœa at Bulama, on the west coast of Africa,[5] produced by the water of a well; the water was itself pure, but was milky from suspended matters, consisting of débris of plants, chlorophyll, minute cellular and branched *algæ*, *monads*, *polygastrica*, and minute particles of sand and clay. When filtered the water was quite harmless.

(*d*) *Dissolved Animal Organic Matter.*—The opinion is very widely diffused that dissolved and putrescent animal organic matter, to the amount of 3 to 10 grains per gallon, may produce diarrhœa. This is possibly correct, but two points must be conceded—1*st*, That there are usually other impurities which aid the action of the organic matter; and 2*d*, That organic matter, even to the amount of 10 to 15 grains per gallon, may exist without bad effects, if it be perfectly dissolved. In the latter case the water is, however, always clear and sparkling, never tainted or discolored. The frequent presence of other impurities renders it difficult to assign its exact influence to dissolved organic matters.

In the case of a well-ventilated court in Coventry,[6] where diarrhœa was constantly present, the water contained 5.68 grains per gallon of volatile and combustible matter, but then it contained also no less than 105 grains of fixed salts, which, as the water had a permanent hardness of 51.6° (Clark's scale) after boiling, must have consisted of calcium and magnesium sulphates and chlorides. It also contained alkaline salts, nitrates, and ammonia. The composition was therefore so complex, that it is difficult to assign to the organic matter its share in the effects.

The animal organic matter derived from graveyards appears to be especially hurtful; here also ammonium and calcium nitrites and nitrates may be present.

(*e*) *Dissolved Vegetable Matter.*—There is some evidence to show that

[1] Virchow's Archiv, band xxvi., p. 117.
[2] British Medical Journal, Oct., 1870.
[3] Ilisch, quoted by Roth and Lex, Mil.-Gesundheitspfl., p. 24.
[4] Canstatt's Jahresb., 1862, vol. ii., p. 31.
[5] Report on Hygiene by Dr. Parkes, Army Medical Report, vol. v., p. 428.
[6] Greenhow, Second Report of the Medical Officer of the Privy Council, 1860, p. 75.

this produces diarrhœa. Wanklyn cites the case of the Leek workhouse and also that of Biddulph Moor, in both of which vegetable matter in solution appeared to produce diarrhœa.

(*f*) *Fetid Gases.*—Water containing much hydrogen sulphide will give rise to diarrhœa, especially if organic matter be also present. In the Mexican War (1861–62), the French troops suffered at Orizaba from a peculiar dyspepsia and diarrhœa, attended with immense disengagement of gas and enormous eructations after meals. The eructed gas had a strong smell of hydrogen sulphide.[1] This was traced to the use of water from sulphurous and alkaline springs; even the best waters of Orizaba contained organic matter and ammonia in some quantity. The experiments of Professor Weber have shown what marked effects are produced by the injection of hydrogen sulphide in solution in water into the blood; is it possible that water containing animal organic matter may occasionally form SH_2 after absorption into the blood, and that the poisonous effect of some water may be owing to this? The symptoms of poisoning by water contaminated by sewage are sometimes very like those noted by Weber in his experiments, viz., diarrhœa and even choleraic symptoms (lowering of temperature), and irritation of the lungs, spine, liver, and kidneys.

The absorption of sewer gases, as when the overflow-pipe of a cistern opens into the sewers, will cause diarrhœa. This seems perfectly proved by the case recorded by Dr. Greenhow, in Mr. Simon's second report.[2]

(*g*) *Dissolved Mineral Matters*, if passing a certain point, produce diarrhœa. Boudin refers to an outbreak of diarrhœa at Oran, in Algiers, which was distinctly traced to bad water, and ceased on the cause being removed; the composition of the water is not explicitly given, but it contained lime, magnesia, and carbonate of soda. Sulphates of lime and magnesia also cause diarrhœa, following sometimes constipation. The selenitic well waters of Paris used to have this effect on strangers. Parent-Duchâtelet[3] noticed the constant excess of patients furnished by the prison of St. Lazare, in consequence of diarrhœa, and he traced this to the water, which "contained a very large proportion of sulphate of lime and other purgative salts;" and he tells us that Pinel had noticed the same fact twenty years before in a particular section of the Salpêtrière. In some of the West Indian stations, the water drawn from the calcareous formation has been long abandoned, in consequence of the tendency to diarrhœa which it caused.

Calcium nitrate waters also produce diarrhœa. A case is on record, in which a well water was obliged to be disused, in consequence of its impregnation with butyrate of calcium (105 grains per gallon), which was derived from a trench filled with decomposing animal and vegetable matters.[4]

Brackish water (whether rendered so by the sea, or derived from loose sands) produces diarrhœa in a large percentage of persons, and at some of the Cape frontier stations water of this character formerly caused much disease of this kind. In a water examined at Netley, which became brackish from sea water, and which produced diarrhœa in almost all persons,

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[1] Poncet, in Rec. de Mem. de Med. Mil., 1863, p. 218. The exact words are "une odeur d'acid sulfurique," but "sulfhydrique" must be meant.

[2] Second Report of the Medical Officer of the Privy Council, Parl. Paper, 1860, p. 153.

[3] Hygiène Publique, t. i., p. 236.

[4] Zeitschrift fur Hygiene, vol. i., p. 166. See also a remark on the effect of calcium and potassium nitrate in causing a tendency to diarrhœa in the Report on the Drainage of Berlin (Die Kanalisation von Berlin, 1868, pp. 27, 28).

the amount of chloride of sodium was found to be 253 grains per gallon. But, doubtless, a much less quantity than this, especially if chloride of magnesium be present, will act in this way.

(*h*) *Metallic Impregnation.*—Occasionally animal organic matter acts in an indirect way, by producing nitrites and nitrates, which act on metals.

Dr. Bædeker,[1] a physician in Witten, was called to some cases of sickness produced apparently by water. On examining the point, he found the water was drawn from a pump with a copper cylinder, and contained a considerable quantity of copper, which seemed to be in combination with some organic matter.[2] Lead (as might have been anticipated) was also largely present in this water, as leaden pumps were used; iron, on the contrary, was not dissolved.

Dysentery.

Dysentery also is decidedly produced by impure water, and this cause ranks high in the etiology of dysentery, though perhaps it is not the first.

Several of the older army-surgeons refer to this cause. Pringle does so several times, and also Donald Munro.[3] In the West Indies, Lemprière,[4] in 1799, noticed the increase of bowel complaints in Jamaica in May, when, after floods, the water was bad and turbid, "and loaded with dirt and filth." He also mentions, that at Kingston and Port Royal the dysentery was owing to brackish water. It was not, however, for many years after this that fresh sources of water were sought for in the West Indies, and that rain-water began to be used when good spring or river water could not be got.

Davis[5] mentions as a curious fact, in reference to the West Indies, that ships' crews, when ordered to Tortola, were "invariably seized with fluxes," which were caused by the water. But the inhabitants who used tank (*i.e.*, rain) water were free; and so well known was this, that when any resident at Tortola was invited to dinner on board a man-of-war, it was no unusual thing for him to carry his drinking water with him.

The dysentery at Walcheren, in 1809, was in no small degree owing to the bad water, which was almost everywhere brackish.

The epidemic at Guadaloupe, in 1847, recorded by Cornuel, seems also quite conclusive as to the effect of impure water in causing not merely isolated cases, but a wide-spread outbreak.[6]

In 1860, at Prague, there were many cases of dysentery, clearly traced to the use of water of wells and springs rendered foul by substances washed into the water by heavy floods. Exact analyses were not made.

On the west Coast of Africa (Cape Coast Castle), an attack of dysentery was traced by Surgeon-Major Oakes to the passage of sewage from a cesspool into one of the tanks. "This was remedied, and the result was the almost total disappearance of the disease."

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[1] Pappenheim's Beiträge, heft iv., p. 49.

[2] The amount of copper required to produce poisonous symptoms appears to be doubtful. It is said that the miners in the desert of Attacama, in South America, prefer to use water containing so much copper as to have a distinct green color, rather than the water brought up from the wells near the shore in skins, which give it an unpleasant taste. It is true that it is used for making coffee, and may thus be to a certain extent purified.

[3] Campaigns in Flanders and Germany.

[4] Vol. i., p. 25.

[5] On the Walcheren Fever, p. 10.

[6] See a review by the late Dr. Parkes on Dysentery, in the British and Foreign Medical and Chirurgical Review for 1847, for fuller details of this epidemic.

That in the East Indies a great deal of dysentery has been produced by impure water, is a matter too familiar almost to be mentioned (Annesley; Twining). Its constant prevalence at Secunderabad, in the Deccan, appears to have been partly owing to the water which percolated through a large graveyard. One of the sources of water contained 119 grains of solids per gallon, and in some instances there were 8, 11, and even 30 grains per gallon of organic matter.[1]

Champouillon[2] has recorded a case in which two regiments used the impure water from the Canal de l'Ourcq, near Paris. One regiment mixed the water with coffee or red wine, the tannin of which united with the organic matter; this regiment had no dysentery. The second regiment used brandy, which precipitated the organic matter on the side of the vessel, where it putrefied. This regiment suffered from dysentery; the substitution of red wine for brandy stopped the disease.

The great effect produced by the impure water of Calcutta in this way has been pointed out by Chevers.[3]

In time of war this cause has often been present; and the great loss by dysentery in the Peninsula, at Ciudad Rodrigo, was partly attributed by Sir J. M'Grigor to the use of water passing through a cemetery where nearly 20,000 bodies had been hastily interred.

The impurities which thus produce dysentery appear to be of the same kind as those which cause the allied condition, diarrhœa. Suspended earthy matters, suspended animal organic matter, calcium and magnesium sulphates and chlorides, calcium and ammonium nitrates, large quantities of sodium and magnesium chlorides in solution, appear to be the usual ingredients; but there are few perfect analyses yet known.[4]

The observations which prove so satisfactorily that the dysenteric stools can propagate the disease, make it probable that, as in the case of typhoid fever and cholera, the accidental passage of dysenteric evacuations into drinking water may have some share in spreading the disease.

2. AFFECTION OF OTHER MUCOUS MEMBRANES BESIDES THE ALIMENTARY.

Little has yet been done to trace out this point. At Prague, after the severe flood of 1860, bronchial catarrh was frequent, probably caused chiefly by the chills arising from the great evaporation; but it was noticed that bronchial catarrh was most common when the drinking water was foulest and produced dysentery. Possibly the bronchial and the urinary mucous membranes may also suffer from foul water; the point is well worthy of close investigation.

3. SPECIFIC DISEASES.

That some of the specific diseases are disseminated by drinking water is a fact which has only attracted its due share of attention of late years. It is certainly one of the most important steps in etiology which has been

[1] Indian Report, p. 44.

[2] Rec. de Mem. de Med. Mil. 1872, Sept., p. 230.

[3] Indian Annals. No. 17, p. 70, 1864.

[4] A localized epidemic of dysentery occurred in some barracks at Nürnberg in the summer of 1872, 30 cases and 4 deaths taking place among the soldiers. The absorption of putrefaction gases from the cloaca in the wings of the building by the drinking water, was considered to be the cause; the water contained nitrates and free ammonia. An individual predisposition to the disease appeared, however, to be also necessary. (Schmidt's Jahrbücher, 1874, vol. i., p. 25.)

made in this century, and the chief merit of its discovery is due to the late Dr. Snow.

Malarious Fevers.

Hippocrates states that the spleens of those who drink the water of marshes become enlarged and hard; and Rhazes not only asserted this, but affirmed that it generated fevers. Little attention seems to have been paid to this remark, and in modern times the opinions of Lancisi, that the air of marshes is the sole cause of intermittents, has been so generally adopted, that the possibility of the introduction of the cause by means of water, as well as of air, was overlooked. Still, it has been a very general belief among the inhabitants of marshy countries, that the water could produce fever. Henry Marshall [1] says that the Singhalese attribute fevers to impure water, "especially if elephants or buffaloes have been washing in it," and it is to be presumed that he referred to periodical fevers. On making some inquiries of the inhabitants of the highly malarious plains of Troy, during the Crimean war, Dr. Parkes found the villagers universally stated, that those who drank marsh water had fever at all times of the year, while those who drank pure water only got ague during the late summer and autumnal months. The same belief is prevalent in the south of India; and in Western Candeish, Canara, Balaghut, and Mysore, and in the deadly Wynaad district, it is stated by Mr. Bettington of the Madras Civil Service, that it "is notorious that the water produces fever and affections of the spleen." The essay by this gentleman [2] gives, indeed, some extremely strong evidence on this point. He refers to villages placed under the same conditions as to marsh air, but in some of which fevers are prevalent, in others not; the only difference is, that the latter are supplied with pure water, the former with marsh or nullah water full of vegetable debris. In one village there were two sources of supply,—a tank fed by surface and marsh water, and a spring; those only who drank the tank water got fever. In a village (Tulliwaree) no one used to escape the fever; Mr. Bettington dug a well, the fever disappeared, and, during fourteen years, had not returned.

Another village (Tambatz) was also "notoriously unhealthy;" a well was dug, and the inhabitants became healthy. Nothing can well be stronger than the positive and negative evidence brought forward in this paper.

Dr. Moore [3] also noted his opinion of malarious disease being thus produced; and M. Commaille [4] has since stated, that in Marseilles paroxysmal fevers, formerly unknown, have made their appearance, since the supply to the city has been taken from the canal of Marseilles. In reference also to this point, Dr. Townsend, the Sanitary Commissioner for the Central Provinces in India, mentions in one of his able reports [5] that the natives have a current opinion that the use of river and tank water in the rainy season (when the water always contains much vegetable matter) will almost certainly produce fever (*i.e.*, ague), and he believes there are many circumstances supporting this view. In this way the prevalence of ague in dry elevated spots is often, he thinks, to be explained. He mentions also that the people who use the water of streams draining forest lands and rice fields "suffer more severely from fever (ague) than the inhabitants of the open plain drawing their water from a soil on which wheat grows. In

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[1] Topography of Ceylon, p. 52. [2] Indian Annals, 1853, p. 526. [3] Ibid., 1867.
[4] Rec. de Mém. de Méd. Mil., Nov., 1868, p 427.
[5] For 1870, published at Nagpore in 1871, para. 143 et seq.

the former case there is far more vegetable matter in the water. The Upper Godavery tract is said to be the most agueish in the province, yet there is not an acre of marshy ground; the people use the water of the Godavery, which drains more dense forest land than any river in India.

In the "Landes" (of southwest France), the water from the extensive sandy plain contains much vegetable matter, obtained from the vegetable deposit, which binds together the siliceous particles of the subsoil. It has a marshy smell, and, according to Fauré, produces intermittents and viscéral engorgements. Dr. Blanc, in his papers on Abyssinia, mentions that on the march from Massowah to the highlands, Mr. Prideaux and himself, who drank water only in the form of tea or coffee, entirely escaped fever, while the others who were less careful suffered, as Dr. Blanc believes, from the water.

The same facts have been noticed in this country. Many years ago Mr. Blower of Bedford mentioned a case in which the ague of a village had been much lessened by digging wells, and he refers to an instance in which, in the parish of Houghton, almost the only family which escaped ague at one time was that of a farmer who used well-water, while all the other persons drank ditch water.[1]

At Sheerness the use of the ditch water, which is highly impure with vegetable debris, has been also considered to be one of the chief causes of the extraordinary insalubrity.[2]

At Versailles a sudden attack of ague in a regiment of cavalry was traced to the use of surface water taken from a marshy district.[3]

The case of the Argo, recorded by Boudin,[4] is an extremely strong one. In 1834, 800 soldiers in good health embarked in three vessels to pass from Bona in Algiers to Marseilles. They all arrived at Marseilles the same day. In two vessels there were 680 men without a single sick man. In the third vessel, the Argo, there had been 120 men; thirteen died during the short passage (time not given), and of the 107 survivors no less than 98 were disembarked with all forms of paludal fevers, and as Boudin himself saw the men, there was no doubt of the diagnosis. The crew of the Argo had not a single sick man.

All the soldiers had been exposed to the same influences of atmosphere before embarkation. The crew and the soldiers of the Argo were exposed to the same atmospheric condition during the voyage; the influence of air seems therefore excluded. There is no notice of the food, but the production of malarious fever from food has never been suggested. The water was, however, different—in the two healthy ships the water was good. The soldiers on board the Argo had been supplied with water from a marsh, which had a disagreeable taste and odor; the crew of the Argo had pure water. The evidence seems here as nearly complete as could be wished.[5]

One very important circumstance is the rapidity of development of the malarious disease and its fatality when introduced in water. It is the same thing as in the case of diarrhœa and dysentery. Either the fever-

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[1] Snow On the Mode of Communication of Cholera, 2d edit., 1855, p. 130.

[2] Is it not possible that the great decline of agues in England is partly due to a purer drinking water being now used? Formerly, there can be no little doubt, when there was no organized supply, and much fewer wells existed, the people must have taken their supply from surface collections and ditches, as they do now, or did till lately, at Sheerness.

[3] Grainger's Report on Cholera, Appendix (B), page 95; foot-note.

[4] Traité de Géographie et de Statistique Médicales, 1857, t. i., p. 142.

[5] Ritter, Hirsch in Jahresb. für gen. Med. for 1869, p. 192.

making cause must be in larger quantity in the water, or, what is equally probable, must be more readily taken up into the circulation and carried to the spleen, than when the cause enters by the lungs.

In opposition, however, to all these statements must be placed a remark of Finke's,[1] that in Hungary and Holland marsh water is daily taken without injury. But in Hungary, Dr. Grosz states that, to avoid the injurious effects of the marsh water, it is customary to mix brandy with it, "a custom which favors hypertrophies of the internal organs."[2] Professor Colin, of the Val de Grâce, who is so well known for his researches on intermittent fever,[3] is also inclined to question the production of paroxysmal fevers by marsh water. He cites numerous cases in Algiers and Italy, where impure marsh water gave rise to indigestion, diarrhœa, and dysentery, but in no case to intermittent fever, and in all his observations he has never met with an instance of such an origin of ague. He therefore denies this power, and in reference to the celebrated case of the Argo, without venturing to contest it, he yet views it with suspicion, and questions whether Boudin has given the exact details.

An instructive case, however, is recorded by Brigade-Surgeon Faught.[4] The artillery quartered at Tilbury Fort (in the Gravesend district) have generally suffered more or less from ague, whilst the people at the railway station, and the coast-guard and their families in the ship lying just outside the fort, never suffer from malarious poisoning. The troops have been supplied with drinking water from two underground tanks which receive rain-water from the roof of the barracks, whilst the other persons above mentioned draw their drinking-water from a spring near the railway station. From December, 1873, to July, 1874, the troops were supplied from the same source, on account of the barrack tanks being out of repair. The following table shows the returns of sickness :

Date.	Strength.	Admissions for Ague.	Percentage of Admissions.	Ratio of Admissions per annum.	Water used.
1872. Jan. to June ...	103	34	33	66	Water from barrack tanks
1873. Jan. to June....	102	12	11.8	23.6	Water from barrack tanks.
1873–4. Dec., 1873, to July, 1874....	90	1*	1.1	1.9	Water from spring at the railway station.
1874–5. Nov., 1874, to March, 1875..	53	4†	7.6	22.8	Water from barrack tanks.

The analyses of the waters showed that the tanks were exposed to soakage from the surrounding salt marsh, for the so-called rain-water yielded 41.3 grains per gallon of total solids in the one case, and 145.25 in the other, the chlorine being respectively 12.8 and 33.9. The station water gave 38 grains total solids and only 3.3 of chlorine. As regards organic matter, the tank waters showed actually less impurity than the station water by the ammonia method, but by the permanganate method they were three times as impure. For full details and for the microscopic examination, see the original paper.

* This case was in hospital only five days: it occurred only a few days after the arrival of the battery.
† None of these had ever had ague before; two had to be sent on furlough, being much debilitated by malaria.

[1] Oesterlen's Handb. der Hygiene, 2d edit., 1857, p. 129 ; foot-note.
[2] Quoted by Wutzur, Reise in dem Orient Europas, band i., p. 101.
[3] De l'Ingestion des eaux Marécageuses comme cause de la Dysentérie et des Fièvres Intermittentes, par L. Colin, Paris, 1872.
[4] Army Medical Reports, vol. xvii., p. 212.

Another case of importance is that recounted by C. Smart, Capt. and Assist.-Surg., U. S. A.[1] In the Rocky Mountain district of North America a fever prevails, which is popularly known as the *Mountain fever;* it is evidently malarious, and is amenable to quinine. There is, however, no malarious district in the neighborhood, and cases of intermittent fever from the plains recover rapidly there, and the disease occurs sometimes when the thermometer is at times below zero, and always below the freezing-point, but most frequently at times when fever does not occur in the plains, but which coincide with the melting of the snows, viz., May, June, and July. Dr. Smart found that all the water in the rivers contained a large excess of organic matter, the purest showing from 0.19 to 0.28 per million of albuminoid ammonia, whilst the springs showed only 0.10. The amount was much increased after heavy snow-fall, and on analyzing the snow he was surprised to find it contains a large excess of organic matter, especially that which fell in large heavy flakes (as high sometimes as 0.58 of albuminoid ammonia). Dr. Smart concludes that vegetable organic matter is blown up from the plains and precipitated with the snow, and, when the latter melts, carried into the streams. At stations where care is taken with the water-supply, and especially where suspended matter is prevented as much as possible from getting into the water, the disease is slight.[2]

The possibility of the transmission of the poison of paroxysmal fevers through drinking-water must be looked upon as still more probable, should the views of Klebs and Tommasi-Crudeli be definitely confirmed.

Typhoid Fever.

The belief that typhoid fever can spread by means of water as well as air appears to be quite of modern origin, though some epidemics, such as the "Schleim-fieber" of Göttingen in 1760, were attributed in part to the use of impure water. In 1822, Walz, at Saarlouis, in 1843, Müller, at Mayence, and in 1848, E. A. W. Richter, at Vienna, published cases illustrative of this.[3] In 1852, Dr. Austin Flint[4] published the particulars of a similar outbreak of typhoid fever at the hamlet of North Boston (Erie, U. S.) in 1843.

In 1852–53, a severe outbreak of typhoid fever took place at Croydon, and was thoroughly investigated by many competent observers; and it was shown by Dr. A. Carpenter that it was partly, at any rate, spread by the pollution of the drinking water from the contents of cesspools.

In 1856, Dr. Routh[5] and in 1859, Dr. W. Budd[6] published very conclu-

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[1] For details see A.M.D. Reports, vol. xix., p. 190.

[2] In my Report on Hygiene, A.M.D. Reports, vol. xviii., an analysis is given of the water of the Rakus Tal Lake on the northern side of the Himalayan range, the sample having been brought home by Lieut.-Col. H. Knight, late 19th Regiment of Foot. In this water the saline ammonia was 0.56 and the albuminoid 0.70 per million. Contrast this with Loch Katrine and other lakes in this country, where the respective amounts are under 0.02 and 0.05, and we have a difference which requires explanation. May it not be that in this country we have so much less snow as a feeder of our mountain lakes, and also fewer districts from which winds could carry up organic matter?—[F. de C.]

[3] All these cases are related by Riecke in his excellent work, Der Kriegs und Friedens-Typhus. Nordhausen, 1850, pp. 44–58.

[4] Clinical Reports on Continued Fever. By Austin Flint, M.D. Buffalo, 1852, p. 380.

[5] Fæcal Fermentation as a Cause of Disease. Pamphlet. Lond., 1856, p. 34.

[6] Lancet, Oct. 29, 1859, p. 432.

sive cases. The latter had long been convinced of the *occasional* propagation of typhoid fever in this way.

In 1860 an outbreak of typhoid fever occurred at the Convent of Sisters of Charity at Munich. 31 persons out of 120 were attacked between 15th September and the 4th of October with severe illness, and 14 of these cases were true typhoid; 4 died. The cause was traced to wells impregnated with much organic matter (and among other things typhoid dejections), and containing nitrates and lime. On the cessation of the use of this water, the fever ceased.[1]

The propagation of typhoid fever in Bedford would certainly appear, from Mr. Simon's report,[2] to have been partly through the medium of the water. Dr. Schmitt[3] has for several years paid particular attention to this point, and in 1861 published several very striking cases.

A case bearing on the same point was brought before the Metropolitan Officers of Health in 1862,[4] by Mr. Wilkinson of Sydenham. In this case the water was contaminated by absorption of sewer gases.

In 1862 a very sudden and severe outbreak of typhoid in a barrack at Munich was traced to water impregnated with fæcal matter;—on ceasing to use the water, the disease disappeared.[5] In 1865 a very remarkable outbreak of typhoid occurred at Ratho, in Scotland, and was traced to drinking water contaminated with sewage.[6] In 1866 typhoid fever broke out in a girls' school at Bishopstoke, near Southampton, and was traced unequivocally to the bursting of a sewer pipe into the well. The water was disagreeable both to smell and taste. 17 or 18 persons were affected out of 26 or 28. Several very striking instances are recorded in Mr. Simon's Reports by Drs. Seaton, Buchanan, and Thorne,[7] and in some of these cases analyses of the water were made, which showed it to be impure, and to contain organic sewage, or its derivatives. A very good case, at the Garnkirk works in Glasgow, is recorded by Dr. Perry.[8] Dr. De Renzy, the Sanitary Commissioner of the Punjab, has also published a remarkable paper on the extinction of typhoid fever in Millbank Prison, and shows, from the statistics of many years, that the fever has entirely disappeared since the use of

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[1] Edinburgh Medical Journal, Jan., 1862, p. 1153. See also Gietl, Die Ursachen des Enter. Typhus in München, 1865, p. 58.

[2] Third Report of the Medical Officer of the Privy Council, 1860.

[3] Journ. de Med. de Bruxelles, Sept., 1861; and Canstatt's Jahresb. for 1861, band iv., pp. 182, 183. See the 2d edition of this work for a short account of them.

[4] British Medical Journal, March 1, 1862.

[5] Gietl, Die Ursachen des Ent. Typhus in München, 1865, p. 62. In this little book is much evidence to show the propagation of typhoid by foul water and by deficient arrangements for removal of excreta, as well as many instances of the carrying of the disease from place to place, analogous to those narrated by Bretonneau many years ago.

[6] Edin. Med. Journ., Dec., 1865. In this case a groom came to the house ill with typhoid from Dundee, and thus introduced the disease.

[7] Dr. Seaton's Report on Tottenham (Report of Medical Officer to the Privy Council for 1866, p. 215). Dr. Buchanan on Guildford (Ibid. for 1867, p. 34); Dr. Thorne's Report on Terling (Ibid., p. 41); Dr. Buchanan's Report on Wicken-Bonant (12th Report, p. 72). In all these instances the evidence reaches the highest degree of probability, and in the cases of Guildford and Wicken-Bonant of almost absolute certainty. See also Report on Sherborne by Dr. Blaxall; on Caius College, Cambridge, by Dr. Buchanan (both in No. ii., new series); on Lewes by Dr. Thorne (No. iv., new series); also the case of Over-Darwen (Sanitary Record, 1875); case given by Dr. Stallard (Lancet, Feb., 1872); Dr. Barclay's Reports on Bangalore (Army Med. Reports, vol. xiii., p. 208). Geissler also quotes from Hägler a very strong case occurring at Lausen. (Schmidt's Jahrb., 1874, No. 2, p. 185.)

[8] Lancet, June, 1868.

Thames water was given up; the disappearance was coincident with the change in the water supply. Two excellent cases are recorded by Dr. Clifford Allbutt[1] and one by Dr. Wohlrab, which are free from ambiguity.[2] A very good case is recorded by Dr. Latham.[3] Typhoid was introduced into a village, and spread by the agency of contaminated drinking water.[4]

A destructive outbreak took place at Caterham and Redhill during 1878. This was investigated by Dr. Thorne Thorne, who traced it to contamination of the water-supply by the stools of a workman suffering from mild typhoid, who was employed in the Company's wells. The disease was confined to those who consumed the water, and ceased after the wells were pumped out and cleansed. The inmates of the Lunatic Asylum and the detachment of troops at Caterham barracks used the water from the asylum well, and did not suffer.[5]

That water may be the medium of propagating typhoid thus seems to be proved by sufficient evidence; and it has been admitted by men who have paid special attention to this subject, as Jenner, W. Budd, and Simon.

Two questions arise in connection with this subject—

1. As typhoid fever undoubtedly spreads also through the air, What is the proportion of cases disseminated by water, as compared with those disseminated by air? No answer can yet be given to this question.[6]

There is one point of some interest. When the dates of attack are given, it is curious to observe how short the incubative period appears to be; while it is probable that it takes many days (8 to 14) after the typhoid poison has entered with the air before the early malaise comes on, in some of the cases of typhoid brought on by water, two or three days only elapse before the symptoms are marked.[7]

A very large number also of the susceptible persons who drink the water are affected.

2. Will decomposing sewage in water produce typhoid fever, or must the evacuations of a typhoid patient pass in? This is part of the larger question of the origin and propagation of specific poisons. It is certainly remarkable, in the range of cases recorded by Schmitt, how uniformly the possibility of the passage of typhoid stools is disregarded. Everything is attributed to fæcal matters merely. A case recorded by Dr. Downes,[8] in

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[1] See Report on Hygiene, Army Med. Dept. Blue Book, 1860, p. 23.

[2] Archiv der Heilk., vol. xii., p. 134 (1871).

[3] Lancet, July 15, 1871.

[4] A remarkable case is reported by Dr. Zuckschwerdt occurring in the orphan asylum at Halle in 1871. Also by Dr. Burkart at Stuttgart, at Reinhartsdorf in Switzerland, and at Schandau, all distinctly traceable to impure water. (Schmidt's Jahrbücher, 1874.)

[5] See Report, by Dr. Thorne Thorne; also A.M.D. Reports, vol. xx., p. 222.

[6] Mr. Simon, in his second Report, new series, gives a table of 146 outbreaks investigated by his officers in 1870–73 (4 years), in all of which great excremental pollution of air or water, or generally of both, was found. Biermer, from an analysis of 1,300 cases, cites evidence of water carriage (Schmidt's Jahrb., 1873, No. 8, p. 195).

[7] Dr. W. Budd says, in a letter to the late Dr. Parkes,—"In the cases in which the poison is conveyed by water, infection seems to be much more certain; and I have reason to think that the period of incubation is materially shortened. An illustration of this seems to be furnished by the memorable outbreak which occurred at Cowbridge some years ago, and which presented this unexampled fact: that out of some 90 or 100 persons who went to a race ball at the principal inn there, more than one-third were within a short time laid up with fever. In this case there was satisfactory reason to think that the water was contaminated, though there was no chemical examination." In the attack at Guildford, however, the incubative period was not shortened, as Dr. Buchanan calculates it at 11 days; neither was it shortened at Caterham.

[8] Lancet, April 27, 1872.

which six cases of typhoid resulted from the overflow of non-typhoid sewage into a well, supports this view. On the other hand, in the cases recorded by Allbutt and Wohlrab, already referred to, contaminated water had been used for some time without producing typhoid fever. Persons affected with typhoid (enteric) fever then entering the place, their discharges passed into the drinking water, and then an outbreak of typhoid followed. An extremely strong case is given by Ballard.[1] Very polluted water had been used for years by the inhabitants of the village of Nunney without causing fever, when a person with enteric fever came from a distance to the village, and the excreta from this person were washed into the stream supplying the village. Between June and October, 1872, no less than 76 cases occurred out of a population of 832 persons. All those attacked drank the stream water habitually or occasionally. All who used filtered rain or well water escaped, except one family who used the water of a well only 4 or 5 yards from the brook. The case seems quite clear—first, that the water caused the disease ; and secondly, that though polluted with excrement for years, no enteric fever appeared until an important case introduced the virus. Positive evidence of this kind seems conclusive, and we may now safely assume that the presence of typhoid evacuations in the water is necessary. Common fæcal matter may produce diarrhœa, which may perhaps be febrile,[2] but for the production of enteric fever the specific agent must be present. The opinion that the stools of typhoid are the special carriers of the poison was first explicitly stated by Canstatt,[3] and was also ably argued by W. Budd.

Cholera.

Few of the earlier investigators of cholera appear to have imagined that the specific poison might find entrance by the means of drinking-water. There is an intimation of the kind in a remark by Dr. Müller ;[4] and Jameson [5] alludes to the effect of impure water, but in a cursory way.

In 1849 the late Dr. Snow, in investigating some circumscribed outbreaks of cholera in Horsleydown, Wandsworth, and other places, came to the conclusion that, in these instances, the disease arose from cholera evacuations finding their way into the drinking water. Judging from the light of subsequent experience, it now seems extremely probable that this was the case, and to Dr. Snow must certainly be attributed the very great merit of discovering this most important fact. At first, certainly, the evidence was defective,[6] but gradually fresh instances were collected, and in 1854

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[1] Report to the Local Government Board, on an outbreak of enteric fever at Nunney, Sept., 1872.

[2] A good instance is given by Mr. R. Bond-Moore (London Medical Record, May 27, 1874, page 327), as occurring at Sedgely Park school. Two years previously the water supply became contaminated with ordinary sewage, but no typhoid fever resulted, although there was diarrhœa, sickness, great languor, and great prostration. The leaking drain was repaired, and the attack ceased. Two years after, typhoid was introduced by one of the boys, and spread apparently by the use of the closets.

[3] "Wahrscheinlich sind die Exhalationen des Krankes, seine Excremente, *vielleicht die typhösen Aftergebilde im Darme,* die Träger des Contagiums."—Canstatt, Spec. Path. und Ther., 2d edit., band ii., p. 572 (1847).

[4] Einige Bemerkungen über die Asiat. Cholera. Hanover, 1848, p. 36.

[5] Bengal Report of 1820.

[6] There seemed at once an *a priori* argument adverse to this view, as, at that time, all evidence was against the idea of cholera evacuations being capable of causing the disease. They had been tasted and drunk (in 1832) by men, and been given to animals, without effect. Persons inoculated themselves in dissections constantly, and

occurred the celebrated instance of the Broad Street pump in London, which was investigated by a committee, whose report, drawn up by Mr. John Marshall, of University College, with great logical power, contains the most convincing evidence that, in that instance, at any rate, the poison of cholera found its way into the body through drinking-water.[1]

In 1855 Dr. Snow published a second edition of his book, giving an account of all the cases hitherto known, and adding some evidence also as to the introduction in this way of other specific poisons.[2]

The facts, at present, may be briefly summed up as follow :—

1. Local outbreaks, in which contamination of the drinking-water was either proved or in which the evidence of the origin and succession of cases seemed to make it certain that the cause was in the drinking-water. In England, Dr. Snow and others have thus recorded cases occurring in 1849 and 1854 at Horsleydown, Broad Street, Wandsworth, West Ham, etc. In 1865 the important outbreak at Newcastle-on-Tyne,[3] when all the circumstances pointed very strongly to the influence of the impure Tyne water. In 1865 occurred the remarkable and undoubted case of water poisoning at Theydon Bois, recorded by Mr. Radcliffe,[4] and in the following year the violent outbreak in the East of London was supposed to be connected with the circulation of impure water by the East London Water Works Company. Much discussion has taken place as to the real influence of the impure water, which it is admitted on all hands was used. Mr. Radcliffe[5] and Dr. Farr[6] collected the evidence in favor of the opinion that the sudden outburst was really owing to this water; while Dr. Letheby and some others expressed doubts on this point, chiefly on account of the difficulty of reconciling with the hypothesis certain exceptional cases both of immunity and of attack. The evidence in favor of the water being the cause appears extremely strong, and far greater difficulty arises if that view is not received than is caused by the exceptional cases referred to, and of which we may not know all the particulars. In the same year (1866) an apparently unequivocal case of production of cholera by the drinking of water of a tank on board a steamer occurred at Southampton.[7]

A very striking case at Utrecht is noticed by Snellen, and is given by Dr. Ballot, of Rotterdam, who has adduced much strong evidence on the influence of the foul water in Holland in spreading cholera.[8]

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bathed their hands in the fluids of the intestines; in India the pariahs who removed excreta, and everywhere the washerwomen who washed the clothes of the sick, did not especially suffer. And to these arguments must be added the undoubted fact, that there were serious deficiencies of evidence in Dr. Snow's early cases. (See review by Dr. Parkes in the British and Foreign Medical Chirurgical Review, April, 1855.)

[1] Report on the Cholera Outbreak in St. James's, Westminster, in 1854. London, Churchill, 1855. Every point is discussed in this Report with a candor and precision which leaves nothing to be desired. For further evidence on this outbreak, see Indian Sanitary Report: evidence of Dr. Dundas Thomson, p. 272.

[2] On the Mode of Communication of Cholera. By John Snow, M.D. London, Churchill, 2d edition, 1855.

[3] For full particulars, see Dr. Farr's Report on Cholera in England, 1866, p. 33.

[4] Report of the Medical Officer to the Privy Council for 1865 (Eighth Report), p. 438.

[5] Report of the Medical Officer to the Privy Council for 1866, p. 266.

[6] Report on the Cholera Epidemic of 1866 in England. Supplement to the 29th Annual Report of the Registrar-General, 1868.

[7] Report of Medical Officer to Privy Council for 1866, p. 244. In this case the water was foul tasted, and was certainly contaminated with sewage.

[8] Medical Times and Gazette, May, 1869. Thus it was found that those who drank the water of the Polders (reclaimed lands) died at the rate of 17.7 per 1,000; those who drank the well-water, 16.8 per 1,000; those who drank river-water, 11.9 per

During the epidemic in 1866, except in the East London case, no such striking instances of local outbreak from water contamination were recorded as in 1849, but there were in some parts, and especially in Scotland, as noticed by Dr. Stevenson Macadam,[1] very striking coincidences between the abatement of the disease and the introduction of a fresh and pure supply.

In Germany choleraic water-poisoning has not only been less noticed, but the great authority of Pettenkofer is against its occurrence. At Munich, Pettenkofer[2] could find no evidence whatever in favor of the spread by water, nor does he consider that any further evidence was furnished by the epidemics in Germany in 1873–74.[3] Even Hirsch, who was favorable to the water theory, expresses himself with considerable caution;[4] and Günther, in his careful work on Cholera in Saxony,[5] asserts that no influence whatever was exerted by drinking-water. No evidence could be obtained either in Baden or in villages near Vienna.[6] And as in all cases the observers were not only quite competent, but were fully cognizant of the opinions held in England, this negative evidence is of great weight. At the same time, it cannot be allowed to outweigh the English cases, and, moreover, even in Germany some positive evidence has been given. Dr. Richter[7] attributes a preponderant influence in a local outbreak among the workmen of a sugar-manufactory to the pollution of the drinking water by sewage; and a still more striking case is recorded by Dr. Dinger,[8] in which the discharges of a cholera patient passed into a brook, in which also the clothes were washed; the water of this brook being used for drinking, there was a sudden and very fatal outbreak affecting the persons who took the water.

In India the evidence for cholera water poisoning has now become very strong. The great cholera outbreak of 1860 and 1861 was attributed by some medical officers to the defilement of the tank water "into which the general ordure of the natives is washed during the rainy season;"[9] and still more recently, what appears to be a striking instance has occurred. No one can read the able account given by Dr. Cuningham and Dr. Cutliffe[10] of the appearance of cholera among the vast crowd of pilgrims after the great bathing day at Hurdwar, without coming to the conclusion that it was a case of water-poisoning on a gigantic scale. Cholera broke out again at Hurdwar in 1879 (the pilgrimage takes place every twelve years), but in his report on this epidemic Dr. J. M. Cuningham endeavors to throw doubts upon the propagation by means of water. The circum-

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1,000; those who drank rain-water filtered, only 5.3 per 1,000. The city of Amsterdam itself, supplied by an aqueduct with rain-water from the downs near Haarlem, had only 4 per 1,000. In Rotterdam, during the epidemic, the mortality fell to one-half immediately on pure water being supplied in the streets. (See paper by J. C. Jäger.)

[1] Transactions of the Royal Scottish Society of Arts, vol. vii., p. 341 (1867).

[2] Zeitsch. für Biol., band i., p. 353.

[3] Ueber Cholera und deren Beziehung zur parasitären Lehre, von Max von Pettenkofer, 1880.

[4] Bericht der Commission des Deutschen Reiches, heft i., saite 13.

[5] Die Indische Cholera in Sachsen im Jahre 1865, p. 125.

[6] Volz and Witlacil, quoted by Hirsch in Jahresb. der gen. Med. for 1867, band ii., p. 221.

[7] Archiv der Heilk., 1867, p. 472.

[8] Ibid., p. 84.

[9] M'William, Epidem. Society Trans., vol. i., p. 274.

[10] Report of the Sanitary Commissioner with the Government of India for 1867. Calcutta, 1868.

stances, however, were very similar in the two cases.[1] Drs. T. Lewis and Douglas Cunningham discredit the influence of water;[2] and Dr. D. Cunningham says,[3]—"One point seems worthy of remark, and that is, that there is no evidence of the existence of any common condition affecting local sources of water supply, and simultaneously affecting the prevalence of cholera and bowel-complaints."

That in India, however, the cholera poison is often carried by water appears probable, not only from the Hurdwar outbreaks, but from the very sudden and violent outbreaks and the great sewage contamination in the water of many districts.[4]

In Central India Dr. Townsend[5] has given strong reasons for believing that the cholera of 1868–69 was, to a large extent, dependent on water-fouling. Dr. Macnamara[6] has given some good evidence on the same side, and Dr. Cleghorn[7] has noted some striking proofs of the same fact.[8]

Dr. M. C. Farnell, Sanitary Commissioner of Madras, points out the immunity of Madras from cholera since the new water supply was obtained from the Red Hills; the same immunity extending to the districts using the water, whereas other places which do not use it still suffer from the disease. Guntur always suffered from cholera up to 1868, since which time it has been practically free, following the greater care for the water supply begun by Dr. Biggwither and carried out by Dr. Tyrrell.[9] A remarkable case is recorded by the Rev. J. Delpech, at Vadakencoulam.[10] Cholera was confined to the higher castes, who drank of a particular well exposed to contamination. Among the lower castes none suffered, except one woman who washed for the higher caste women. The lower caste people drank from other wells, which were less exposed to pollution.

So also in other countries; in the attack which caused such losses to the French Division in the Dobrudscha in 1855, when the wells were supposed to be poisoned, and to the English cavalry at Devna,[11] the water was apparently the means of carrying the disease.

In evidence of this kind, we must remember that each successive instance adds more and more weight to the instances previously observed,

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[1] See section vi. of the Sixteenth Annual Report of the Sanitary Commissioner with the Government of India, 1880.

[2] Cholera in Relation to Certain Physical Phenomena.

[3] Medico-Topographical Report on Calcutta.

[4] Vide Report on the Sanitary Administration of the Punjaub for 1867, and subsequent years, by A. C. C. De Renzy, Esq. (Cases of Peshawur and Amritzur.)

[5] Report on Cholera in the Central Provinces.

[6] On Asiatic Cholera, see pp. 328 et seq.

[7] Indian Medical Gazette, March, 1872.

[8] See also the remarkable case of the Yerrauda gaol, reported by Surgeon-Major H. Blanc. Out of 1,279 prisoners there were 24 cases of cholera in 5 days, with 8 deaths. Of those, 22 cases occurred among 134 prisoners employed as a road-gang, and only 2 among all the others variously employed. It was shown that the road-gang alone drank of water from the Mootla River, a little below the spot where the clothes of two cholera patients from the village had been washed and their bodies burnt a few days before. The rest of the prisoners drank the usual water supply laid on from a lake near Poonah. In the two cases among those otherwise employed direct infection was undoubted in one, as he attended on cholera patients, and, contrary to orders, took his meals in the cholera ward, and drank water that had been standing there; the other man slept near one of the first cases, the patient vomiting in his immediate vicinity.

[9] Indian Medical Gazette, April, 1882.

[10] Ibid., December 1, 1879.

[11] MS. essay of Dr. Cattell.

until, from the mere accumulation of cases, the cogency of the argument becomes irresistible.

2. The evidence derived from such local outbreaks is supported by that drawn from the history of more general attacks, in which districts supplied with impure water by a water company have suffered greatly, while other districts in the same locality, and presenting otherwise the same conditions, were supplied with pure water, and suffered very little. Thus the Registrar-General has shown that the districts supplied in 1853, part by the Lambeth Company with a pure water, and part by the Southwark Company with an impure water, suffered much less than the districts supplied by the latter company alone (the proportion was 61 and 94 cases respectively to 100,000 of population). Schiefferdecker, in Königsberg, has also given evidence to show the different extent in which districts in the same city supplied with pure and impure water suffer.[1]

In Berlin, in 1866, in the houses supplied with good water the number of houses in which cholera occurred was 36.6 per cent.; in the houses with bad water was 52.3 per cent.[2]

3. Additional arguments can be drawn from instances in which towns which could not have had water contaminated with sewage have escaped, and instances in which towns which have suffered severely in one epidemic have escaped a later one, the only difference being that, in the interval, the supply of water was improved. Exeter, Hull, Newcastle-on-Tyne, Glasgow, and Moscow are instances of this. Two very good cases are related by Dr. Acland.[3] The parish of St. Clement was supplied in 1832 with filthy water from a sewer-receiving stream. In 1849 and 1854 the water was from a purer source. In the first year, the cholera mortality was great; in the last years, insignificant. In Copenhagen a fresh water supply was introduced in 1859. Although cholera had prevailed very severely there previously, in 1865 and 1866 there were only a few cases.[4] In Haarlem, in Holland, cholera prevailed in great intensity in 1849. In 1866 it returned, and again prevailed as severely in all parts of the town except one. The part entirely exempted in the second epidemic was inhabited by bleachers, who, between 1849 and 1866, had obtained a fresh source of pure water.[5]

In looking back, with this new reading of facts, it would seem that some older reported cases of sudden cessation of cholera can be explained, such as the case of Breslau, in 1832, when the shutting up of a pump was followed by the very rapid decline of the disease. Doubtless, however, in other cases the causes of the cessation are different; heavy rain, by cleansing air and sewers, and by stopping the evolution of effluvia, will sometimes as suddenly arrest cholera. Most important evidence is given by Professor Förster of Breslau.[6] He shows that five towns of Silesia (of 5,000 to 12,000 inhabitants) are entirely free from cholera, which never spreads, even when introduced. The only common condition is a water supply from a distance which *cannot* be contaminated. In Glogau (13,000) half the water is from a distance and half from wells: those using the former remain free, those using the latter are attacked. In one case in Breslau, on a well becoming

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[1] See Report on Hygiene, Army Med. Dept. Report, vol. xii., p. 241.
[2] Die Kanalisation von Berlin, 1868, p. 30.
[3] Cholera in Oxford in 1854, by H. W. Acland, M.D., p. 51.
[4] Hornemann in Virchow's Archiv, band 53, p. 156.
[5] Ballot, British Med. Journal, April, 1869.
[6] Die Verbreitung der Cholera durch die Brunnen, Breslau, 1873.

contaminated, eleven persons were immediately attacked.[1] Dr. A. Fergus[2] has pointed out that in Glasgow, when the whole city was supplied from the river, cholera was universal in 1848 ; whilst in 1854 it was chiefly confined to the north side, which still drew water from the river, the south side with a pure water supply being practically free from it. In 1866 the whole city had the pure Loch Katrine supply, and, although cases of cholera were imported, it got no hold on the city whatever.

So also other curious facts in the history of cholera become explicable. The prevalence of cholera in Russia, with an outdoor temperature below zero of Fahr., has always seemed an extraordinary circumstance, which it appeared only possible to explain by supposing that, in the houses, the foul air and the artificial temperature must have given the poison its necessary conditions of development. But Dr. Routh has pointed out[3] that, in the poorer Russian houses, every thing is thrown out round the dwellings ; then, owing to the cold and the expense of bringing drinking water from a distance, the inhabitants content themselves with taking the snow near their houses and melting it. It is thus easy to conceive that, if cholera evacuations are thus thrown out, they may be again taken into the body. This is all the more likely, as cholera stools have little smell or taste, and, when mixed even in large quantity with water, cannot be detected by the senses.

We may therefore conclude that the cholera evacuations, either at once or after undergoing some special fermentative or transformation change, pass into drinking water or float about in the atmosphere. In either case they are received into the mouth and swallowed, and produce their effects directly on the mucous membrane, or are absorbed into the blood. The relative frequency of each occurrence, the incubative period, and the severity of the disease produced, are points still uncertain.

C. Macnamara states[4] that the dangerous period is when the water into which cholera stools are passed is swarming with vibriones, and that when ciliated infusoria appear danger is over. He speaks strongly on this point, and from actual experience.

In addition to the production of cholera from drinking-water containing the cholera stools, it has been supposed that the use of impure water of any kind *predisposes* to cholera, though it cannot absolutely produce the disease. The facts already quoted on the influence of the Lambeth water seem to support this view ; but some German evidence in 1866 does not favor it,[5] although later evidence seems to do so.[6] If the water acts in this way, it may be by causing a constant tendency to diarrhœa, or by carrying into the alimentary canal organic matter which may be thrown into special chemical changes by a small quantity of cholera poison, which has been introduced with air or food and swallowed, or by lowering the resistance of the body, and rendering it more favorable as a nidus for the poison.

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[1] In India also similar results are found. Cullen cites the case of Hurda, rendered free from cholera by improved conditions of water supply. Payne reports that the new water supply of Calcutta has had the strongest effect in diminishing the mortality from cholera. See also the Report on the Cholera in America in 1873, for cases of water carriage.

[2] British Medical Journal, 1879, vol. ii., p. 336.

[3] Fæcal Fermentation, p. 24.

[4] Asiatic Cholera, p. 330.

[5] See Report on Hygiene, Army Medical Dept. Report, vol. vii., p. 325.

[6] Pistor of Oppeln, Cholera Epidemic of 1873–74 ; see 6th part of the Report of the Cholera Commissioners of the German Empire.

Yellow Fever.

As, like dysentery, typhoid fever, and cholera, the alimentary mucous membrane is primarily affected in yellow fever, there is an *à priori* probability that the cause is swallowed also in this case, and that it may possibly enter with the drinking-water. But no good evidence has been yet brought forward.

Boudin [1] quotes a case from Rochard in which a French frigate (in 1778) took in water at San Jago, where yellow fever prevailed. Some days afterward yellow fever broke out with such violence that two-thirds of the crew were attacked. "And the proof that the only cause was the water," says Rochard, "was that the persons living with the captain had with them jars filled with water from Europe, and all escaped." Boudin very properly observes, that this evidence is very defective; but yet we must remember how completely the propagation of marsh and typhoid fevers, and of cholera by water, has been overlooked, and how exactly this sudden and extensive attack resembles the case of the Argo.

The Barrack Commissioners have also directed attention to the fact of the great impurity of the water at Gibraltar at the time of the yellow fever epidemic; a difficulty which still remains to be dealt with in the event of the introduction of any epidemic disease.

The other Zymotic Diseases.

Of the other zymotic diseases the only ones likely to be propagated by means of water are *scarlet fever* and *diphtheria.* The evidence for such propagation was formerly very slight, but since attention has been drawn to the subject numerous cases have occurred which have been attributed to water-poisoning,—working either directly through water drunk as such, or by its being mixed with milk. There seems no *primâ facie* reason against such a channel of infection in the case of scarlet fever, particularly as epithelium scales are so often found in contaminated water. As regards diphtheria, the question is a little more complicated, for the direct communication through the use of the same drinking vessel might simulate water carriage, as pointed out by Dr. A. Downes.[2] Some important evidence has, however, been collected by Dr. B. Browning [3] and others. It would also appear that ordinary throat ulcer (if this be really different from diphtheria) may be propagated in this way. It has been suggested that *erysipelas* is sometimes due to contaminated water, but of this, however, there is as yet no conclusive evidence.

4. DISEASES OF THE SKIN, AND SUBCUTANEOUS TISSUES.

A curious endemic of boils occurred in the vicinity of Frankfort in 1848. It was confined to a small number of persons, and presented favorable opportunities for investigation. An elaborate inquiry was made by Dr. Clemens,[4] which certainly seems to indicate that the complaint was caused by drinking water containing hydrogen sulphide gas, which was set free in some large chemical works, and was washed down by the rains into the

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[1] Traité de Géog. et de Stat. Méd., 1858, t. i., p. 141.
[2] Sanitary Record, 1879–80, vol. xi., p. 51.
[3] Ibid., p. 13.
[4] Henlè's Zeitschrift für Nat. Med., 1849, vol. viii., p. 215.

brooks from which drinking-water was derived. The case is most elaborately and logically argued, but it certainly seems remarkable that other instances of the same kind should not have been observed, especially as in some trades there is disengagement of large quantities of SH_2 into the atmosphere, and as the drinking of sulphuretted springs is so common.

The peculiar forms of boil or ulcer common in many cities in the East have been in some cases referred to the water. The Aleppo evil, the Damascus ulcer, and some other diseases of an analogous kind, which have the peculiarity of occurring only once in life, are possibly more connected with the true contagions; but the unhealthy boils or ulcers so common in India, especially in the northwest and along the frontier, are probably connected with bad water. The so-called Delhi boil has much decreased in frequency since the waters of the Jumna were used instead of the impure well-water,[1] but, on the other hand, Fleming's observations have thrown doubt on the fact of the water being to blame. The later observations of Drs. D. Cunningham and T. Lewis have tended, on the other hand, to weaken those of Fleming, and to show that the water is probably to blame. With regard to the frontier ulcers in India, Dr. Alcock, A.M.D., has given some curious evidence, which seems to connect them with vegetable detritus and the evolution of hydrogen sulphide.

The elephantiasis of the Arabs (the so-called Barbadoes leg or Pachydermia) has been ascribed to organic impurities in water, which may be true, if the disease, as is now suggested, be due to a *Bacillus* which might be conveyed in water.

5. DISEASES OF THE BONES.

Water, impregnated with sulphurous acid, gives rise in cattle to a number of serious symptoms, among others to diseases of the bones. The sulphur dioxide evolved from the copper works at Swansea has caused numerous actions on account of the loss of herbage and cattle. Rossignol[2] states that water highly charged with calcium carbonate and sulphate was found to give rise to exostoses in horses; pure water being given, the bones ceased to be diseased.

6. CALCULI.

It has long been a popular opinion that drinking lime waters gives rise to calculi (calcium phosphate and oxalate). Several medical writers have held the same opinion, and have adduced individual instances of calculi (phosphatic ?) being apparently caused by hard waters, and cured by the use of soft or distilled water. On a large scale, statistical evidence is apparently wanting. The excess of cases of calculi in Norwich and Norfolk generally is not, in Dr. Richardson's opinion, attributable to the water.[3] Dr. J. Murray, of Newcastle, has given some evidence[4] to show a connec-

[1] See Annual Report of San. Com. with the Government of India for 1867, p. 178 (1868). Some excellent analyses of the Delhi waters are given by Dr. Sheppard; *vide* D. Macnamara's Second and Third Reports of the Analyses of Potable Waters in the Bengal Presidency. Calcutta, 1868.

[2] Traité d'Hygiène Militaire, 1857, p. 357.

[3] Med. History of England; Medical Times and Gazette, 1864, p. 100.

[4] British Medical Journal, September, 1872.

tion between the lime waters and calculi, especially phosphatic, but it does not appear to be more convincing than that previously adduced.

At Canton stone is common, while at Amoy, Shanghai, Ningpo, and other places, it is not met with. The cause of the difference is not known, but it is not calcium carbonate in the water, as the Chinese always drink boiled water.[1]

Professor Gamgee, however, states that sheep are particularly affected by calculus in the limestone districts.

7. GOITRE.

The opinion that impure drinking water is the cause of goitre is as old as Hippocrates and Aristotle, and has been held by the majority of physicians. The opinion may be said actually to have been put to the test of the experiment, since both in France and Italy the drinking of certain waters has been resorted to, and apparently with success, for the purpose of producing goitre, and thereby gaining exemption from military conscription.[2] And this is supported by the evidence of Bally, Coindet, and by many of the French army surgeons, who have seen goitre produced even in a few days (eight or ten) by the use of certain waters.[3] While, conversely, Johnston saw goitre, which was common in a jail, disappear when a pure water was used.[4] Apart from this, the evidence for the causation by water is extremely strong, many cases being recorded where, in the same village, and under the same conditions of locality and social life, those who drank a particular water suffered, while those who did not do so escaped.[5] The latest author who has written on this subject, and who has accumulated an immense amount of evidence, M. Saint-Lager, expresses himself very confidently on the point.

The impurity in the water which causes goitre is not yet precisely known. It is certainly not owing to the want of iodine, as stated by Chatin, and there is little probability of its being caused by organic matters, by fluorine, or by silica. On the other hand, the coincidence of goitre with sedimentous water is very frequent. Since the elaborate geological inquiries of M. Grange[6] and the analyses of the waters of the Isère, magnesian salts in some form have often been considered to be the cause, to which many add lime salts also ; and certainly the evidence that the waters of goitrous places is derived from limestone and dolomitic rocks, or from serpentine in the granitic and metamorphic regions, is very strong. The investigations now include the Alps, Pyrenees, Dauphiné, some parts of Russia, Brazil, and districts in Oude in Northwest India. A table compiled from Dr. M'Clellan's work[7] is very striking :—

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[1] Dr. Wang, in Chinese Customs Report for 1870, p. 71.

[2] Among other evidence on this point. the work of M. Saint-Lager (Sur les causes du Cretinisme et du Goitre endémique, Paris, 1867) may be cited (p. 191 et seq.), as he appears to have carefully looked into the evidence. See also Baillarger (Comptes Rendus de l'Acad., t. lv., p. 475), who states, though this has been denied by Rey, that horses and mules become affected from drinking the water of the Isère.

[3] Encyclopædia of Practical Medicine, vol. i., art. Bronchocele, p. 326.

[4] Edin. Monthly Journal, May, 1855.

[5] Saint-Lager (op. cit.) cites several strong cases (p. 192 et seq.).

[6] Ann. de Chimie et de Phys., vol. xxiv., p. 364.

[7] Medical Topography of Bengal. The facts on cretinism are also included, without desiring to express any opinion on the relation between goitre and cretinism.

Goitre and Cretinism in Kumaon (*Oude*).

Water derived from	Percentage of Population affected.	
	With Goitre.	With Cretinism.
Granite and gneiss	0.2	0
Mica, slate, and hornblende	0	0
Clay slate	0.54	0
Green sandstone	0	0
Limestone rocks	33	3.0

There are, however, not wanting analyses of water of goitrous regions which show that magnesia may be absent (in Rheims, according to Maumenè ; in Auvergne, according to Bertrand ; in Lombardy, according to Demortain ; and Saint-Lager enumerates other cases), while it has been also denied that there need be any excess of lime. M. Saint-Lager, basing his opinion partly on these negative instances, partly on his own experiments with the soap-test, which show no relation between hardness of water and goitre, and partly on the negative results of experiments on animals with calcium sulphate and magnesian salts, denies altogether the connection between goitre and calcium and magnesium sulphates and carbonates. He states also that M. Grange has now himself given up the belief of magnesia being the essential agent of goitre,[1] and argues that the constituent of the water which is the actual cause is either iron pyrites (ferrum sulphide), or more infrequently copper or some other metallic sulphide. And he explains M'Clellan's results by the supposition, based on an expression of that writer, that in the limestone districts of Kumaon the water had traversed the metalliferous strata of the rocks. Saint-Lager does not support his opinion by actual chemical analyses, but he brings forward geological evidence on a large scale, to prove that the endemic appearance of goitre coincides with the metalliferous districts. He has also made experiments on animals with iron salts, which do not appear conclusive, although he believes he produced in some cases an effect on the thyroid. His hypothesis seems to fail from his want of chemical analyses. He has made out a case for inquiry rather than for conclusion.

In some observations made by Dr. Ferguson on the goitrous part of the Baree Doab district[2] (a boulder-gravel subsoil), the water is said to be largely charged with lime. In the jail at Durham, Johnston[3] states that when the water contained 77 grains per gallon (chiefly of lime and magnesian salts), all the prisoners had swellings of the neck ; these disappeared when a purer water, containing 18 grains in the gallon, was obtained.[4]

Goitre may be rapidly produced. Bally noticed that certain waters in Switzerland would cause it even in eight or ten days, and cases almost as rapid have occurred in other places.[5]

[1] Sur les causes du Cretin. et du Goitre, p. 237.

[2] Sanitary Administration of the Punjab for 1871, Appendix 4, p. 33.

[3] Edin. Monthly Journal, May, 1855.

[4] In Nottingham the people attribute goitre to hardness of water. Generally it appears only with magnesium limestone.

[5] Many instances are recorded in the French military medical journal, Recueil de Mém. de Méd. Mil., of the acute goitre produced in a few days.

Dr. J. B. Wilson (late A.M.D.) carried out some inquiries at Bhagsoo, Dhurmsala, where goitre prevails extensively. He analyzed specimens of the drinking water within a radius of ten miles, and found them exceptionally pure, only three showing traces of lime, and none giving any evidence of magnesia or iron.[1]

It seems, therefore, that the question is still undecided, and it is much to be desired that more extended inquiry should be made, with careful analyses, such as have been made by Dr. Wilson,—as well as records of local and other conditions, which probably contribute more or less to the production of the disease.

8. ENTOZOA, OR OTHER ANIMALS.

Whereas the *Tænia solium* and the *Tænia mediocanellata*, and many entozoa, find their way into the body with the food,[2] the two forms of the *Bothriocephalus latus* (*T. lata*) may pass in with the drinking water.[3] Both embryo and eggs (but principally, or perhaps entirely, the former) exist in the river water. The ciliated embryo moves for several days very actively in water ; it may after a time lose its ciliary covering, and then, not being able to move further, perishes ; or it may find its way into the body of some animal, and there develop into the *Bothriocephalus latus.*

It is most common in the interior of Russia, Sweden, in part of Poland, and in Switzerland.

Distoma hepaticum (*Fasciola hepatica*).—The eggs are developed in water, and the embryos swim about and live, so that introduction in this way for sheep is probable, and for men is possible.

The *Ascaris lumbricoides* (Round-worm) appears also sometimes to enter the body by the drinking water. At Moulmein, in Burmah, during the wet season, and especially at the commencement, both natives and Europeans, both sexes and all ages, were, forty years ago, so affected by lumbrici that it was almost an epidemic.[4] The only circumstance common to all classes was that the drinking water, drawn chiefly from shallow wells, was greatly contaminated by the substances washed in by the floods of the excessive monsoon which prevails there. Dr. Paterson[5] has also noticed similar facts in England.

Leuckart[6] has no doubt of the passage of the *ascarides'* eggs into drinking water ; and, indeed, they have been actually seen in the water by Mosler.[7] But it seems yet doubtful (as all experiments have failed in producing from the drinking water the worms in animals) whether the eggs alone will suffice, and it seems possible that they must pass through some other host before developing in the human intestine. This is also the

[1] Indian Annals of Medical Science ; also Aitken's Science and Practice of Medicine, 7th edit., vol. ii., p. 1009.

[2] Dr. Oliver's observations in India show that cattle may get *tænia* ova from the water ; so that men may do the same. (See Aitken's Med., 7th ed., vol. i., p. 207.)

[3] See especially a paper by Dr. Knoch in the Peterburger Med. Zeitsch. for 1861. An abstract is given in the Lancet, Jan. 25, 1862 ; and the paper in full is printed in Virchow's Archiv, band xxiv., 453. Cobbold, however, doubts the direct entrance in this way, and thinks it more probable that fish form the *host* for the ova, which after development in the fish, may find their way into the bodies of men who eat the fish.

[4] The native treatment is the powder of a fungus (Wah-mo) derived from the female bamboo. It is most useful. See paper by Dr. Parkes in the London Journal of Medicine, 1849.

[5] Aitken's Practice of Medicine, 7th ed., i., p. 157.

[6] Die Menschlichen Parasiten, band ii., p. 220.

[7] Virchow's Archiv, band xviii., p. 249.

opinion of Cobbold. Mosler attributed in his case much influence to the large amount of vegetable food taken by the persons affected.

The *Dochmius duodenalis* (*Strongylus duodenalis*, *Anchylostomum seu Sclerostoma duodenale*) would appear from Leuckart's statement [1] to be introduced by impure water.[2]

Oxyuris vermicularis, very common in children, but occasionally also found in adults, is probably sometimes taken through water.[3]

Filaria Dracunculus (Guinea-worm).—The introduction by water of *Filaria* has long been a favorite opinion. It has been a matter of debate whether it is taken into the stomach as drink, and thence finds its way (like *Trichina*, to the muscles) into the subcutaneous cellular tissue, or whether it penetrates the skin during bathing or wading in streams. The latter opinion seems to be the more probable in the majority of cases.[4]

Boiling the water before drinking appears to have a preservative effect.[5]

Filaria sanguinis hominis (Lewis) appears to find its way into the blood of man through water in a curious way. "Dr. Manson has found that the mosquito is an active agent in the propagation of the *Filaria*. The embryos are taken into the mosquito's stomach with the blood of persons infected by the hæmatozoon, the further development of which shortly begins in the stomach of the mosquito. Thence they are transferred to the water, whence it is assumed that it again finds entrance into the body of man." [6]

Bilharzia hæmatobia.—From the observations of Griesinger, John Harley,[7] and Cobbold, there seems no doubt that the embryos of this entozoon live in water, and the animal may be thus introduced probably by the medium of some other animal. Dr. Batho doubts, however, this introduction by water, since the entozoon occurred in persons using rain-water and pure mountain stream water.[8]

Leeches.—Reference has already been made to the swallowing of small leeches, which fix on the pharynx, and in the posterior nares. Cleghorn [9] noticed that coughs, nausea, and spitting of blood were thus caused. In a march of the French near Oran, in Algiers, more than 400 men were at one time in hospital from this cause. In some cases the repeated bleedings from the larynx have simulated hæmoptysis and phthisis, and have produced anæmia. A leech, once fixed, seldom falls off spontaneously. In India no accidents of this kind are on record, yet we must assume that they occasionally occur.

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[1] Virchow's Archiv, band ii., p. 465.

[2] The importance of the discovery of Griesinger (Archiv für Phys. Heilk., 1854, p. 555), that the so-called widely spread Egyptian chlorosis is caused by *Dochmius duodenalis*, has hardly been sufficiently appreciated. Not only anæmia and liver diseases, but symptoms referred to dysentery and hemorrhoids, are often so produced. And as similar facts have now been observed in Brazil, Arabia, and Madagascar, it seems impossible but that in India the formidable affections caused by *Dochmius* should not be common.

[3] Aitken, vol. i., p. 183.

[4] See Dr. Aitken's long and excellent chapter on this disease, in his Practice of Medicine, 7th ed., vol. i., p. 169, et seq., for a discussion on the water and earth question.

[5] Greenhow, in Indian Annals, 1856, p. 557.

[6] Aitken, op. cit., i., 185.

[7] Med. Chir. Trans., vol. xlvii., p. 65, and vol. lii., p. 379.

[8] Army Med. Rep., vol. xii., p. 504.

[9] Diseases of Minorca, 1768, p. 38.

9. LEAD, MERCURY, ARSENIC, COPPER, AND ZINC POISONING.

It is only necessary to mention the fact of metals passing into the drinking water, either by trade refuse being poured into streams, or by the water dissolving the metal as it flows through pipes or over metallic surfaces.

In 1864 a factory at Basle discharged water containing arsenic into a pond, from which the ground and adjacent wells were contaminated, and severe illness in the persons who drank the well-water was produced.[1]

General Conclusions.

1. An endemic of diarrhœa, *in a community*, is almost always owing either to impure air, impure water, or bad food. If it affects a number of persons suddenly, it is probably owing to one of the two last causes, and if it extends over many families, almost certainly to water. But as the cause of impurity may be transient, it is not easy to find experimental proof.
2. Diarrhœa or dysentery, constantly affecting a community, or returning periodically at certain times of the year, is far more likely to be produced by bad water than by any other cause.
3. A very sudden and localized outbreak of either typhoid fever or cholera, is almost certainly owing to introduction of the poison by water.
4. The same fact holds good in cases of malarious fever, and, especially if the cases are very grave, a possible introduction by water should be carefully inquired into.
5. The introduction of the ova of certain entozoa by means of water is proved in some cases—is probable in others.
6. Although it is not at present possible to assign to every impurity in water its exact share in the production of disease, or to prove the precise influence on the public health of water which is not extremely impure, it appears certain that the health of a community always improves when an abundant and pure water supply is given ; and, apart from this actual evidence, we are entitled to conclude, from other considerations, that abundant and good water is a primary sanitary necessity.

SECTION V.

EXAMINATION OF WATER FOR HYGIENIC PURPOSES.

The analysis of water for hygienic purposes has for its object to ascertain whether the water contains any substances either suspended or dissolved which are likely to be hurtful. There are some substances which we know are not likely to do any harm, such as carbonate of sodium, calcium, and magnesium in small quantities. Others are at once viewed with suspicion as indicating an animal origin, and therefore being probably derived from habitations or resorts of men or animals, or from decaying bodies. In other cases substances in themselves harmless, such as nitrates, nitrites, and ammonia, are suspicious from implying the co-existence of, or the previous contamination of the water by nitrogenous substances. The difficulties in the hygienic examination of water are not inconsiderable. A

[1] Roth and Lex, Milit. Gesundsheitpfl., p. 41.

judgment must be generally come to from a collation of all the evidence, rather than from the results of one or two tests.

Collection.

Great care must be taken that a fair sample of the water is collected in perfectly clean glass vessels (not in earthenware jars)—Winchester quarts, which hold about half a gallon, and can be obtained of most chemists, are most convenient;—they should be repeatedly washed out with some of the water to be examined. In taking water from a stream or lake, the bottle ought to be plunged below the surface before it is filled. In drawing from a pipe, a portion ought to be allowed to run away first, to get rid of any impurity in the pipe. In judging of a town supply, samples should be obtained direct from the mains, as well as from the houses. The bottle should be stoppered; a cork should be avoided, except in great emergency, but if used it should be quite new, well tied down, and sealed.[1] No luting of any kind (such as linseed meal and the like) should be used.

For a complete sanitary investigation half a gallon is necessary, but with a litre or a couple of pints a pretty good examination can be made if more cannot be obtained. If a detailed mineral analysis is required (which will only be seldom) a gallon ought to be provided. It is always advisable to have a good supply in case of breakage or accident. The "W. O. Circulars" direct two Winchester quarts of each sample to be sent.[2] The examination ought to be undertaken immediately after collection, if possible. If this cannot be done, then as short a time as may be should be allowed to elapse,—for changes in the most important constituents take place with great rapidity.[3] Pending examination, it ought to be kept in a dark, cool place.

The fullest information ought always to be furnished with the sample, the following being the most important particulars:—

1. Source of the water, viz., from tanks or cisterns, main or house pipe, spring, river, stream, lake, or well.
2. Position of source, strata so far as they are known.
3. If a well; depth, diameter, strata through which sunk, whether imperviously steined in the upper part, and how far down. Total depth of well and depth of water to be both given. If the well be open, furnished with cover, or with a pump attached.
4. Possibility of impurities reaching the water: distance of well from cesspools, drains, middens, manure-heaps, stables, etc.; if drains or sewers discharge into streams or lakes; proximity of cultivated land.
5. If a surface-water or rain-water, nature of collecting surface and conditions of storage.
6. Meteorological conditions, with reference to recent drought or excessive rainfall.
7. A statement of the existence of any disease supposed to be connected with the water supply, or any other special reason for requiring analysis.

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[1] W. O. Circulars, clause 82, June, 1876; clause 12, January, 1877; and clause 81, April, 1878, direct water to be sent in stoppered glass-bottles.

[2] Frankland recommends from one Winchester quart of the worst waters to three of the purest.

[3] For some interesting experiments on this point, see Hehner, in the Analyst, vol. iii., p. 177.

Any further information that can be obtained will always be useful. Each bottle should also be distinctly labelled, so as to correspond with the official letter or invoice.

When it is possible, it is most desirable that the medical officer or analyst should visit the locality itself whence the water is obtained ; in this way he may obtain information which might otherwise escape him. If the analysis can be made immediately on the spot, it will be all the more valuable.

Sub-Section I.

Physical Examination of Water.

The following points are to be noted :—

1. Color.	4. Lustre.
2. Clearness.	5. Taste.
3. Sediment.	6. Smell.

1. *Color.*—This may be judged of by allowing any sediment to settle, and then pouring off the supernatant water into a tall glass, placed upon a piece of white paper. Or a horizontal tube of colorless glass with glass ends may be used. The stratum should be of sufficient thickness, if possible *two* or *three* feet, but a fair idea of the color may be obtained with 18 inches or even a foot. The Society of Public Analysts recommends 24 inches. If a tube be used, it may either be half full, and the tint compared with the color of the air in the upper half when directed against a well illuminated white surface ; or, better still, it may be filled, and the comparison made with a second tube placed alongside, filled with pure distilled water. Perfectly pure water has a bluish tint, but most ordinary waters have either a grayish, greenish, yellow, or brown appearance. The best samples are those colored bluish or grayish. Green waters owe their color to vegetable matter, chiefly unicellular *algæ*, and are usually harmless. Yellow or brown waters are most to be feared, as their color is often due to animal organic matter, chiefly sewage. It is sometimes, however, owing to vegetable matter, such as peat, and under those circumstances it is not generally hurtful :—it may also be caused by salts of iron, although in most cases the iron is precipitated as ferric oxide in the sediment.

2. *Clearness.*—The presence or absence of turbidity may be judged of in the same way as the color, only the water should be shaken up, so as to distribute the suspended matter and simulate its condition when drawn. The depth necessary to obscure printed matter may be used as a measure. Occasionally water remains hazy or turbid, even after standing for some time; in such a case the suspended matter is in very fine division, such as is sometimes found with sulphate of calcium, minute scales of mica, etc.

3. *Sediment.*—The nature of the sediment may be roughly judged of by the eye, as to whether it is mineral or vegetable, or stained with iron or the like. The larger living forms, such as *Anguillulæ*, water-fleas, leeches, etc., may also be detected. But the only satisfactory examination is to be made with the microscope.

4. *Lustre.*—The lustre or brilliancy (*éclat*) has been recommended as a good physical indication of the amount of aëration (Gérardin). The different degrees may be noted in any convenient way, such as *nil*, *dull*, *vitreous*, or *adamantine*, which is an ascending scale from zero to the maximum brightness.

5. *Taste.*—Taste is an uncertain indication. Any badly tasting water should be rejected or purified before use. Suspended animal organic matters often give a peculiar taste, so also vegetable matters in stagnant waters. Some growing plants, as *lemnia* and *pistia*, give a bitter taste: but most growing plants have no taste. Perfectly dissolved animal matter is frequently quite tasteless. As regards dissolved mineral matters, taste is of little use, and differs much in different persons. On an average—[1]

Sodium chloride	is tasted	when it reaches		75	grains	per gallon.
Potassium "	"	"		20	"	"
Magnesium "	"	"		50 to 55	"	"
Calcium sulphate,	"	"		25 to 30	"	"
" carbonate,	"	"		10 to 12	"	"
" nitrate,	"	"		15 to 20	"	"
Sodium carbonate,	"	"		60 to 65	"	"
Iron, "	"	"		.2	"	"

Iron is thus the only substance which can be tasted in very small quantities. A permanently hard water has sometimes a peculiar *fade*, or slightly saline taste, if the total salts amount to 35 or 40 grains per gallon, and the calcium sulphate amounts to 6 or 8 grains. The taste of good drinking water is due entirely to the gases dissolved; water nearly free from carbonic acid hardness, such as distilled water, is not so pleasant as the brisk well carbonated waters; it may be called flat, but it is difficult to define the kind of taste or absence of it.[2]

6. *Smell.*—The water may be warmed, or distilled, when the odor of fecal matter is often brought out clearly both in the distillate and residue. If the water is put in a stoppered bottle, which it half fills, and is exposed to light, and then opened and smelt after a few days, commencing putrefaction, or the formation of butyric acid, or something similar, can sometimes be detected. Tiemann recommends that the water should be heated to 110° or 120° Fahr.; if hydrogen sulphide be present, add a little copper sulphate, which precipitates it, and permits any putrid smell to be perceived.

The Society of Public Analysts[3] recommends heating the water in a wide-mouthed stoppered bottle to 100° F. (38° C.). This may be done by immersing it in water. Any particular smell should be recorded, if distinctly recognized—with its degree of intensity, such as *nil, very slight, slight, marked*, etc., as the case may be. Sometimes an offensive smell is detected on *boiling*, which is not otherwise perceived.[4]

Although the *physical characters* give only an imperfect idea of the value of a water, they are yet important when no further examination can be made. If a water be colorless, clear, free from suspended matter, of a brilliant (or adamantine) lustre, devoid of smell or taste, except such as is recognized to be the characteristic of good potable water, we shall in the large majority of cases be justified in pronouncing it a good and wholesome water; whilst, according as it deviates from these characters, we

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[1] Dr. F. de Chaumont, Army Medical Report for 1862 (vol. iv., p. 355).

[2] Arguing from the apparent preference many persons have for water containing some saline matter, Wanklyn has suggested the addition of sodium chloride to drinking water, to the extent of 50 grains per gallon.

[3] N.B.—Where the letters S.P.A. occur, they mean "Society of Public Analysts," and refer to rules published in the Analyst, July and August, 1881.

[4] See Dupré, Analyst, 1878, p. 265.

shall be proportionately justified in regarding it with suspicion. Suspended matter is probably the most dangerous, but it may well be that minute particles, the "resting spores" of disease-causing organisms, may exist without revealing themselves by any visible turbidity (or even to a cursory microscopic examination); nor must we shut our eyes to the possibility of hurtful dissolved substances, so that when our opinion of a water is based only on its physical characters the fact ought to be duly recorded.

Sub-Section II.—Examination of Suspended Matters.

The suspended matters may be either mineral (sand, clay, chalk, fine films of mica, iron peroxide), or dead animal or vegetable matters, or living creatures (plants and animals).

To determine the Nature of the Suspended Matters.

Pour some of the water into a long glass as already described, and observe its appearance. Suspended sand or clay gives a yellow, or yellow-white turbidity; vegetable humus and peat give a darkish, sewage gives a light brown color; but the color or turbidity alone is a very insufficient test. Then boil the water, and pour it back into the long glass. Sand, chalk, and heavy particles of the kind will be deposited; finely suspended sewage and vegetable matter is little affected, unless it be a chalk-water, when the deposit of calcium carbonate may carry down the suspended matter. When the water is commencing to boil, smell it to see if there is any trace of sewage.

Microscopic Examination.[1]

The examination with the microscope can, however, alone give accurate information of the nature of the suspended matters. Very high powers (1,000 or 1,200 diameters) are necessary for a complete examination, though lower powers will give much information.

If the matter is entirely suspended, a drop of the water must be taken at once; but when it can be obtained, a little of the sediment is more satisfactory. To get a sediment, the water should be placed in a conical glass (the space of which ought to be *rounded,* not *pointed,* at the bottom), carefully covered and allowed to stand for a few hours; and the upper part of the water is then poured away or siphoned off. In special cases, where it is important to know the exact condition of the suspended matters, before they undergo change by the action of the atmosphere of the room or laboratory where they may be kept, they should be collected in vacuum tubes and sealed. A very small amount of sediment can be thus got at. An immense number of dead and living things are often found in water, which it would be impossible to enumerate, but which may be conveniently considered under two great and several minor divisions. The best kind of pipette for taking up the sediment for transfer to the glass slide is a plain straight tube, without bulb and without any narrowing to a point at either end;—the diameter may be from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch ($1\frac{1}{2}$ to 3 millimetres).

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[1] For a good resumé of this part of the examination, reference may be made to Professor Macdonald's excellent work, A Guide to the Microscopic Examination of Drinking-water, by J. D. Macdonald, R.N., F.R.S., Deputy Inspector-General of Hospitals and Fleets, Professor of Naval Hygiene, Army Medical School.

1. INANIMATE SUBSTANCES.

(*a*) *Mineral particles* may be easily known; sand appears as large angular particles, often showing distinct conchoidal fracture; clay and marl as round smooth globules unaffected by acids; carbonate of calcium (chalk) sometimes smooth, but often crystalline, soluble in acids with effervescence. Iron peroxide appears in reddish brown masses of an amorphous character; it is easily dissolved in acid, and strikes a deep blue with the ferrocyanide of potassium (yellow prussiate).

(*b*) *Vegetable matters:* portions of wood, leaves, bits of the veins, parenchyma, or ducts are easily recognized. When vegetable tissue is more decomposed nothing is seen but a dark, opaque, structureless mass. Any dark formless mass of this kind in water is almost certainly decayed vegetable matter. Bits of textile fabrics (cotton, linen) are not uncommon, and are important as indicating that the water is contaminated with house refuse. So also the cells of the potato, or spiral threads of cabbage and other vegetables used by men, are of value as indications of the same kind. Carbonaceous masses also occur, either portions of soot from coal smoke, or bits of charred wood. Sometimes fragments of paper are met with, probably washed into the water from drains or cesspools.

(*c*) *Animal matters,* consisting of bits of wool, hair, and remains of animals of all kinds, such as wings and legs of insects, spiders and their webs, portions of the skin of water animals, or of fish, etc., are not uncommon. Sewage matters having a darkish brown or reddish color, and often in globular masses, and thus distinguishable from the flatter and more spread-out vegetable matter, are sometimes seen. In the London water, as supplied thirty years ago, Hassall recognized these little "ochreous" masses, and found that nitric acid brought out a pink tint. He thought them to be portions of muscular fibre, tinged with bile. Epithelium (from the skin of men)[1] and hairs of animals are not unfrequent. The identification of these matters is of moment, as indicating the particular source of the contamination. Anything which can be unequivocally traced to the habitations of men must always cause the water to be regarded with suspicion, as, if one substance from a house can find its way in, others may do so too.

2. LIVING ORGANISMS.[2]

These are often found in the sediment, but sometimes also float in the water above the sediment. They are almost innumerable, and as immature forms and various stages of development are seen, it is often difficult or impossible to name all of them.

(*d*) *Bacteria, vibriones, or microzymes.*—Under these terms are meant the small points or jointed rods, sometimes moving rapidly, sometimes slowly or motionless. Distinctions are made between these three by some, while by others the three terms are used as synonyms.[3] High powers (and preferably with immersion lenses) are required to see them properly. When

[1] Epithelium from the skin breaks down slowly in water; soakage for many months does not destroy it. Epithelium from the mouths of cattle is sometimes found. This was the case in some water examined at Netley, got from a catch-pit in Parkhurst Forest.

[2] Numerous plates of the various organisms found in the Thames water have been given by Hassall. (Microscopic Examination of the Water supplied to London, by A. H. Hassall, M.D., 1860. Food and its Adulteration, by the same author, 1876.)

[3] Frequently spoken of as *Bacteroids* and smaller forms as *Bacteriform puncta.*

they appear in water it is necessary, as Lex [1] has shown, that besides oxygen three conditions must be present—(1) an organic carbonaceous substance; (2) a nitrogenous substance, which need not be organic—a nitrate, for example, will well nourish *bacteria,* and is reduced to nitrite by their growth; [2] (3) a phosphate, which, however, may be in exceedingly small quantity. The *bacteria* may either originally exist in the water, or be introduced. Burdon-Sanderson's experiments, however, are not favorable to the introduction of *bacteria* from the air, though large numbers of cells which seem to belong to the same class can be obtained from the air. It appears from Burdon-Sanderson's observations that the germs (if the term be allowed) of *bacteria* may exist in water and be indetectable by the highest microscopic powers, or even by Tyndall's test of the electric beam. To detect these the test by cultivation, or what may be called the *microzyme test for water,* can be employed. Take a little recently prepared clear Pasteur's fluid,[3] boil it, and put one or two C.C. into a test-tube previously strongly heated to 356° Fahr. (180° C.), drop in three or four drops of the water, and close the mouth of the tube with cotton wool. If microzymes or their germs exist in the water, in a few days the liquid becomes milky from countless *bacteridia.*

As, however, even distilled water and the purest ice-water may contain *bacteridia,* the test cannot be used as a positive indication of good or bad water, except in connection with others, and with due regard to temperature, which has a great effect. All it will show is, that the greater or less rapidity of appearance of opalescence will prove that microzymes are more or less abundant.

At present there seems no reason to think that common (putrefactive) *bacteria* and *vibriones* are in themselves hurtful, but they indicate the existence of putrefactive organic matter, which is a danger. But there may be, and probably are, forms of *bacteria* which are more dangerous, and which may hereafter be distinctly differentiated by careful cultivation.

Both *spirillum* and *bacillus* can also be often detected in water. In addition to microzymes the water will always contain various allied *protozoa,* which are usually termed *monads* or *zooglœa,* and which seem to have the same significance as *bacteridia.*[4]

(*e*) *Fungi.*—In any water which contains nitrogenous matter (of animal nature, at any rate), sugar, and a little phosphate, *fungi* will soon appear, and the spores, no doubt, enter from the atmosphere. Spores, spore-cases, and delicate mycelium can be seen, and often *bacteridia* co-exist. If *fungi* are found in water they indicate impurity, and such water should not be used if it can be avoided, or should be purified.[5] Boiling does not kill the *fungi,* according to Heisch; charcoal filtration does so, according to the same observer, though later experience has shown that this is not always

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[1] Centralblatt für die Med. Wiss., No. 20, 1872, p. 305.

[2] Eventually the nitrite disappears, nitrogen being liberated.

[3] Pasteur's fluid is composed of 10 grammes of crystallized sugar; 5 grammes of ammonium tartrate; 1 of well-burnt yeast ash, and 100 C.C. of distilled water. It should be quite clear. It is a capital breeding-ground for microzymes or fungi.

[4] According to Dr. Macdonald, "All analogy would go to indicate that the Zooglœa form of *Bacterium termo* may be regarded as the primary or normal state of this organism, the surrounding gelatinous matter being simply the representative of that which forms the indefinite frond of *Microhaloa,* or *Palmella,* for example" (op. cit., p. 14).

[5] In the cases of malarious fever at Tilbury Fort (Army Med. Reports, vol. xvii.) fungoid structures were found in the water whose use was coincident with the fever, but were absent from the water, following on whose use the fever ceased.

the case. Animal charcoal adds some phosphate to the water, and in this way aids the growth of *fungi*. Spongy iron gives off no phosphate, and water filtered through it is quite freed from *fungi*.

Heisch[1] states that sewage matter in water gives rise, when sugar is added to the water, to a peculiar *fungus*, which he describes as formed of very small, perfectly spherical transparent cells arranged in grape-like bundles ; they grow rapidly into mycelia, and are attended with the special character of producing the odor of butyric acid. The mycelium soon disappears.

Dr. Frankland doubts whether *fungi*, which are readily produced by adding sugar to sewage water, are distinctive of sewage, as apparently similar cells are caused by other animal matters.

The identification of the spores of *fungi*, and even of the mycelium as seen in water, is so extremely difficult that it would be at present rash to affirm that any fungoid elements are distinctive of fecal matter. The butyric acid smell also is given off by so many impure waters that it could hardly be used as a test for fæces.

(*f*) *Algæ, diatoms, and desmids* are found in almost all running streams, and are also seen in many well waters. They cannot be held to indicate any great impurity ; and to condemn water on account of their presence would be really to condemn all waters, even rain, in which minute algoid vesicles (*protococci*) are often found.

The forms of the various *confervæ* in water are very numerous ; some being colored green, whilst at other times they are quite colorless, round, isolated, or clustered vesicles. The immature forms may not be easy of identification. The *diatoms* are always readily recognized and identified. It may be stated generally that organisms of a grass-green color, such as the green *algæ*, need not be objected to ; but the bluish green, such as the *Oscillatorians*, *Nostoc*, etc., are less desirable ; not that they are probably directly injurious, but as indicating an impure water, and as being apt to give rise to an unpleasant ("pig-pen") odor. *Leptothrix ochræa*, which was at one time thought to be connected with a special disease poison, is really harmless, and is mostly found in waters containing a good deal of iron peroxide ; such waters are usually singularly free from noxious organic matter.

(*g*) *Rhizopoda*, especially *amœbæ* and similar forms, may often be detected with high powers. They appear to indicate, like *bacteridia*, the existence of putrefying substances, but this is not yet certain. They are not found in first-class waters.

(*h*) *Euglenæ* (of different species, such as *E. viridis*, *E. pyrum*, etc.) are found in many waters, especially of ponds and tanks.[2] Ciliated, free, and rapidly moving *infusoria*, belonging to several kinds of common *protozoa*, such as *kolpoda*, *paramecium*, *coleps*, *stentor*, *kerona*, *stylonychia*, *oxytricha*, etc., are also found. The abundance of these bodies indicates, of course, that the water contains food for them, and this must be either vegetable or animal organic matter, but the mere presence of these *infusoria* will not show which it is. Hassall noticed, however, in 1850, that the Thames water below Brentford, where it was mixed with sewage, swarmed with *paramecia*, while at Kew, where the water was freer from sewage

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[1] Chemical News, June, 1870.

[2] There appears reason to believe that all or most of the flagellate animalcules are vegetable, and the minuter (such as *monas*) are probably connected with the reproduction of higher forms, such as *fungi*.

matters, they had almost disappeared. Subsequent observations have not, however, proved the relation between *paramecia* and animal matter in the water to be sufficiently constant to allow the former to be used as a test of the latter. Fixed or slow moving *infusoria,* as the *vorticellæ,* are also often seen in river waters.

In many waters the living objects in the above five classes comprise all that are likely to be seen, but in the other cases there are animals of a larger kind.

(*i*) *Hydrozoa,* especially the fresh-water *polyps,* are common in most still waters, and do not indicate anything hurtful.

(*k*) *Worms,* or their eggs and embryos, belonging to the class *Scolecida,* may occur in water, and are of great importance. The eggs and joints of the tape-worm, the embryos of *Bothriocephali,* the eggs of the round and thread worms, and perhaps the worms themselves, the Guinea-worm, and other kinds of *Filaria ;* the eggs of *Dochmius duodenalis,* and other *distomata,* and the embryos of *Bilharzia,* have all been recognized in water, though it has not yet been shown that in all cases they can be thus introduced into the human body. That *Filaria sanguinis hominis* may be taken in drinking-water is most probable, seeing that its host, the mosquito, is developed in water, the larvæ of the latter being found in great quantity in tanks and cisterns. Worms themselves cannot well be overlooked, but both eggs and the free-moving embryos are sometimes difficult of identification. The greatest care should be used in examining water to detect ova. In India, the abundance of minute *Filariæ* has led to the general term of "tank worm" being applied.

The presence of even common *Anguillulæ* in water shows generally an amount of impurity, and such a water must be regarded with great suspicion. Small leeches also are not uncommon in both still and running waters.

The wheel animalcules are common enough, and cannot be regarded as

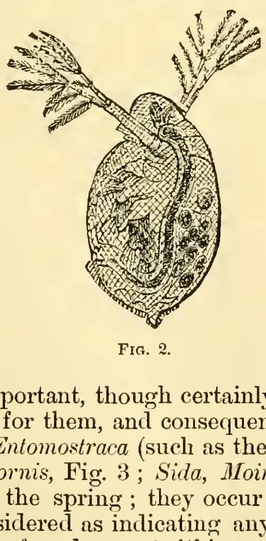


Fig. 2.

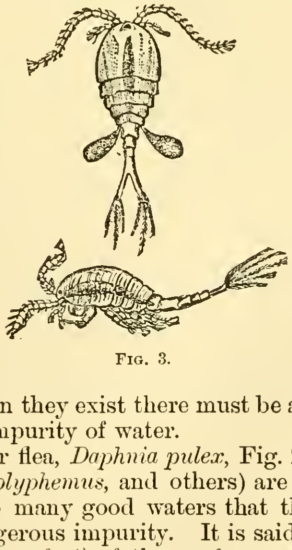


Fig. 3.

very important, though certainly when they exist there must be a good deal of food for them, and consequently impurity of water.

(*l*) *Entomostraca* (such as the water flea, *Daphnia pulex,* Fig. 2 ; *Cyclops quadricornis,* Fig. 3 ; *Sida, Moina, Polyphemus,* and others) are very common in the spring ; they occur in so many good waters that they cannot be considered as indicating any dangerous impurity. It is said that they are only found near (within one or two feet) of the surface. *Amphipoda* (*Gammarus pulex*) may also be met with ; as well as *Isopoda* (*Asellus aqua-*

ticus), and *Tardigrada* (water bears), especially if water that has been stagnant gets washed into tanks, cisterns, or water-butts.

(*m*) There are, of course, many other tolerably large animals often found in water; the larvæ of the water gnat (*Dytiscus*), the water boatman or skip-jack (*Notonecta glauca*), and the pupa form of many insects, may be found, but they are chiefly in pond water.

So many are the objects in water that the observer will be often very much at a loss, first, to identify them, and secondly, to know what their presence implies. The best way is first to see what objects appear to be mineral, or non-living vegetable substances, and to fix the origin and estimate the quantity as far as it can be done. Then to turn to the living organisms and to look attentively for *bacteridia*, *amœbæ*, *fungi*, and *ova*, and small worms and leeches. If none of these exist, the water cannot be considered dangerous. Ciliated *infusoria* of various kinds, *Diatoms*, *Desmids*, and *Algæ*, are chiefly important in connection with microscopic evidence of decaying vegetable matters, and with chemical tests showing much dissolved organic impurity in the water.

The subjoined plates show the principal objects found in a deep well water (Plate I.); in a slow running stream (Plate II.); in Thames water taken in 1868 above Teddington Lock (Plate III.); in water from a spring near Railway at Tilbury (Plate IV.).

Chemical Examination of the Sediment.

The amount of sediment is told by taking two equal quantities of water (say ½ litre), evaporating one quantity to dryness at once, and the other after subsidence and filtration, so that suspended matters are as far as possible separated, and then weighing the two residues. The difference between the two weights gives the amount of the sediment. Or a certain amount of water may be allowed to stand until all the sediment has fallen; the water is poured off, and the sediment dried and weighed. If good Swedish filtering paper is obtainable, the sediment may be obtained at once; two filters should be moistened with dilute hydrochloric acid, then washed with distilled water, and then dried. The amount of ash in one filter should then be determined by incineration; the sediment should be collected on the other filter, dried, weighed, and then incinerated. The ash of the filter itself being known, the weight of the ignited sediment is the total weight, less the ash of the filter. If it be wished to carry the analysis farther, the sediment is incinerated; mineral matter remains, while all animal and vegetable matter, whether previously inanimate or living, is destroyed. This matter of such various origin is generally stated under the vague terms of organic or volatile matter, but this gives no idea of its origin. Some of this so-called organic matter may have been dead; another portion living. The mineral matter may be further determined by digesting in weak hydrochloric acid by the aid of heat; the undissolved matters are silica and aluminium silicate; lime, iron, and magnesia will be dissolved, and can be tested for as hereafter given.

Sub-Section III.—Examination of Dissolved Matters.

In all examinations of water, if the sediment is not expressly referred to, it is to be understood that the examination refers *only* to the dissolved matters. These are gases or solids.

Description of Plate I.

Sediment from South wing Well, Netley, drawn with the Camera lucida *at the distance of* 10 *inches from the centre of eye-piece to paper.*

The presence of infusoria and animals of low type indicates the presence of organic matter, animal or vegetable, and it is therefore important to note their presence ; but it has not at present been shown that they are in themselves at all hurtful.

aaa Actinophrys Sol, early and complete stages, × 260.
b Supposed decomposing amœba-like expansions of Gromia fluviatilis, × 435.
c Fragment of carbonate of lime, × 435.
d Navicula viridis, × 435.
e Grammatophora marina? × 435.
f Supposed encysted stage of Euglena viridis, × 435.
g Pinnate conferva, × 780.
hhh Fragments of decaying vegetable matter, × 65.
ii Fragments of carbonaceous substance.
j Part of conferva filament, Conferva floccosa? showing the various conditions of the protoplasm in the old and new cells, × 435.
k Part of leaf of Sphagnum or bog-moss, × 108.
l Grammatophora marina, × 435.
m Minute spores with zoospores? × 435.
n Diatoma hyalinum, × 435.
o Cell with dividing protoplasm, × 435.
p Oxytricha lingua, × 260.
q Rotifer vulgaris, small, × 108.
r Anguillula fluviatilis, × 108.
s Peranema globosa, × 108.
t Statoblast of a fresh-water zoophyte? × 108.
u Arthrodesmus incus, × 435.
v Minute Desmidiæ, Scenedesmus obtusus, × 780.
w Oscillaria (oscillatoria) lævis, × 780.
x Homœocladia filiformis? × 435.
y Ankistrodesmus falcatus, × 435.
z Minute moving particles, × 435.—(?) Zoospores.

Plate I.

× 65 $\frac{1}{100}$

× 108 $\frac{1}{1000}$

× 260 $\frac{1}{1000}$

× 435 $\frac{1}{1000}$

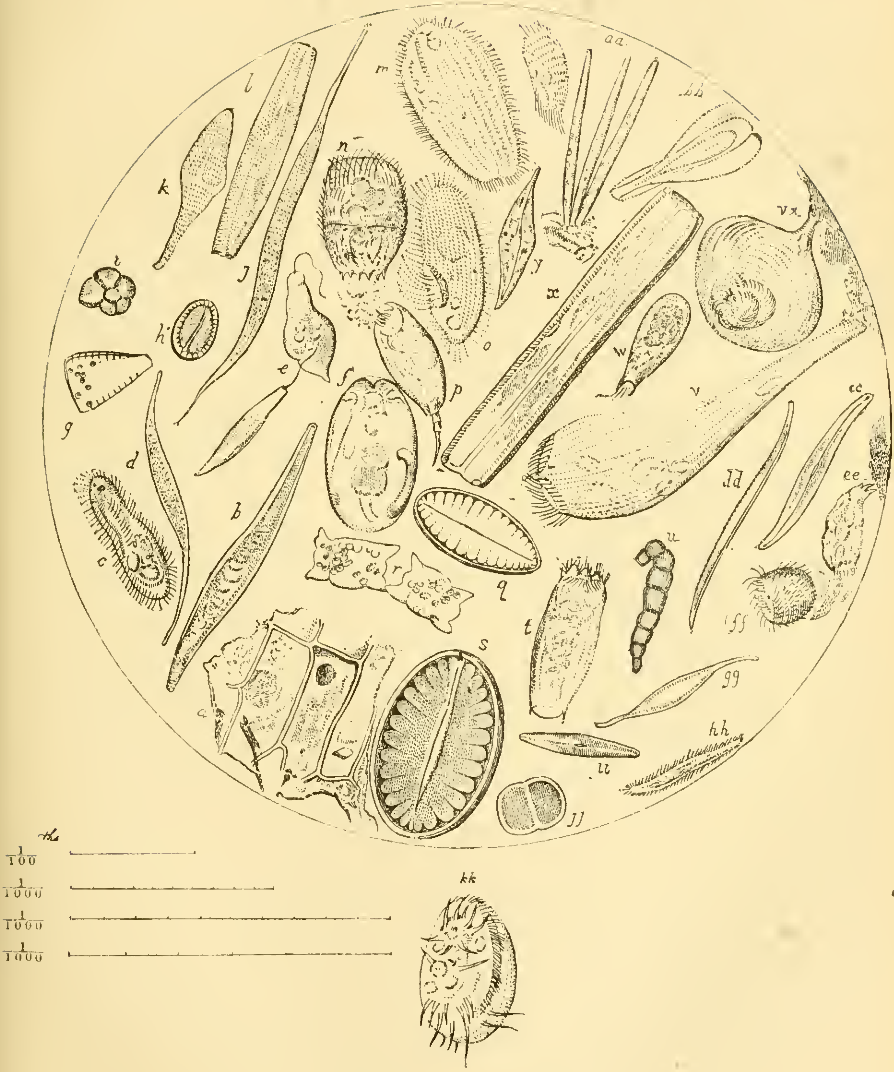
× 780 $\frac{1}{1000}$

Description of Plate II.

Sediment of Ditch Water, drawn with the Camera lucida *at the distance of 10 inches from eye-piece to paper.*

a Decaying vegetable matter, cellular tissue, × 108.
b Pleurosigma formosum, before dividing, × 170.
c Oxytricha gibba, × 108.
d Amphileptus anser, × 170.
e Euglena viridis, × 285.
f Supposed urceola of some rotifer, × 108.
g Surirella gemma, × 108.
h Do. do. × 65.
i Foraminifera, × 65.
j Trachleocerca linguifera, × 65.
k Small Planaria? ovisacs distended, × 65.
l Navicula viridis, × 285.
m Paramecium aurelia, × 170.
n Coleps hirsutus, × 285.
o Pleuronema crassa, × 285.
p Monura dulcis, × 170.
q Surirella splendida, × 170.
r Biddulphia pulchella, × 285.
s Surirella striatula, × 170.
t Rotifer, Monolabis conical? × 108.
u Aregma, spore cases, × 285.
v Stentor ceruleus? do. *v.* × contracted, × 170.
w Trinema acinus? × 170.
x Pinnularia grandis, × 170.
y Gyrosigma angulatum before dividing, × 170.
z Alyscum saltans? × 170.
aa Synedra ulna, × 170.
bb Amphiprora alata, × 285.
cc Gyrosigma Spencerii, × 285.
dd Nitzschia sigma, × 170.
ee Brachionus angularis, × 170.
ff Young Vorticella? × 170.
gg Gyrosigma fasciola, × 285.
hh Trachelius strictus, × 285.
ii Cocconema Boeckii, × 170.
jj Confervoid cell? with divided protoplasm, × 285.
kk Euplotes Charon, × 170.

Plate II.



Description of Plate III.

Drawing of Sediment in Thames Water, taken just above Teddington Lock, in April, 1878. *Notice the evidence of impurities from men, viz., epithelium, woollen, cotton, and flax fibres.*

Fig. 1. Coleps hirsutus.
2. Bodo grandis.
3. Actinophrys Eichornii.
4. Epithelium (tessellated).
5. Leucophrys striata.
6. Anguillula fluviatilis.
7. Paramecium chrysalis, dividing (? sexual stage).
8. Vorticella microstoma.
9. Kerona, young?
10. Vorticella microstoma (stemless).
11. Paramecium aurelia.
12. Conferva.
13. Cocconema lanceolatum.
14. Synedra splendens.
15. Gyrosigma attenuatum.
16. Gomphonema acuminatum.
17. Wool fibre, dyed.
18. Cotton fibre, dyed.
19. Conferva floccosa.
20. Hair, barbed, of?
21. Kerona mytilus.
22. Siliceous spicule.
23. Diatoma vulgare.
24. Fungi (? Torula).
25. Flax fibre.
26. Arthrodesmus quadricaudatus.
27. Stylonichia? histrio, dividing.
28. Paramecium caudatum.
29. Woody fibre, ? rootlets.
30. Pollen.
31. Vegetable tissue and mycelium, with spores.
32. Decaying vegetable matter.
33. Gomphonema curvatum.
34. Spores of Fungi (? Aregma).
35. Antherozoid of?
36. Encysted spore.

Decaying vegetable matter and infusoria abundant.

Plate III.

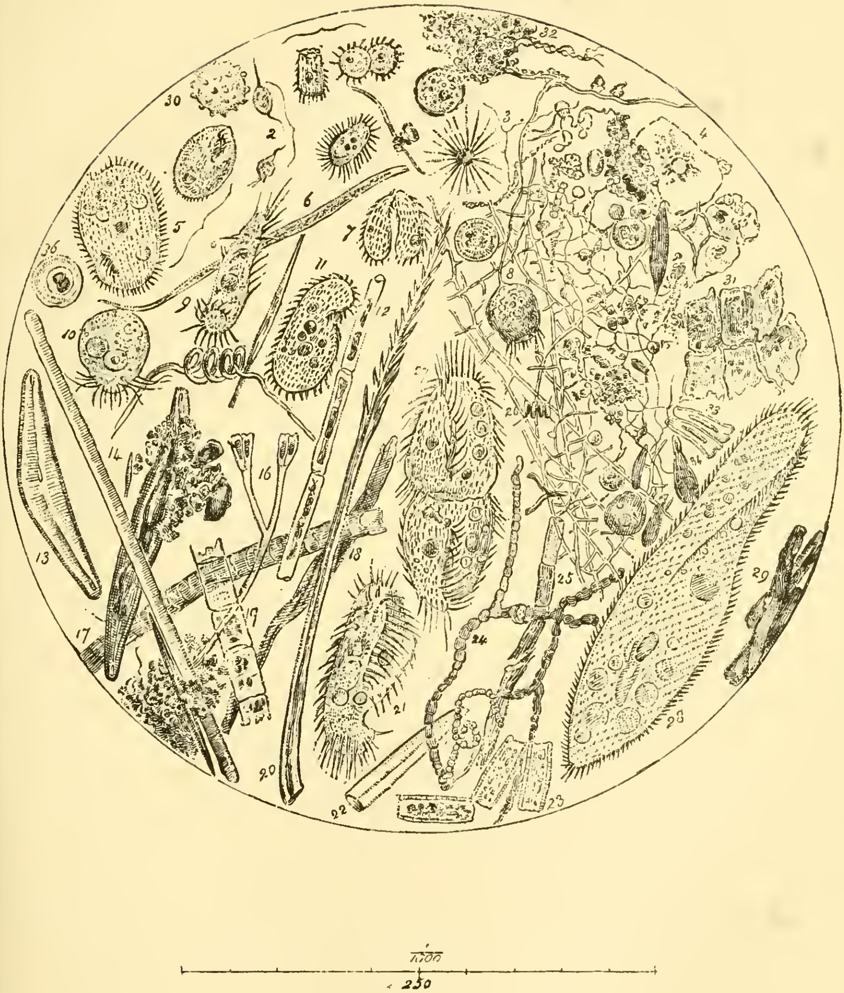
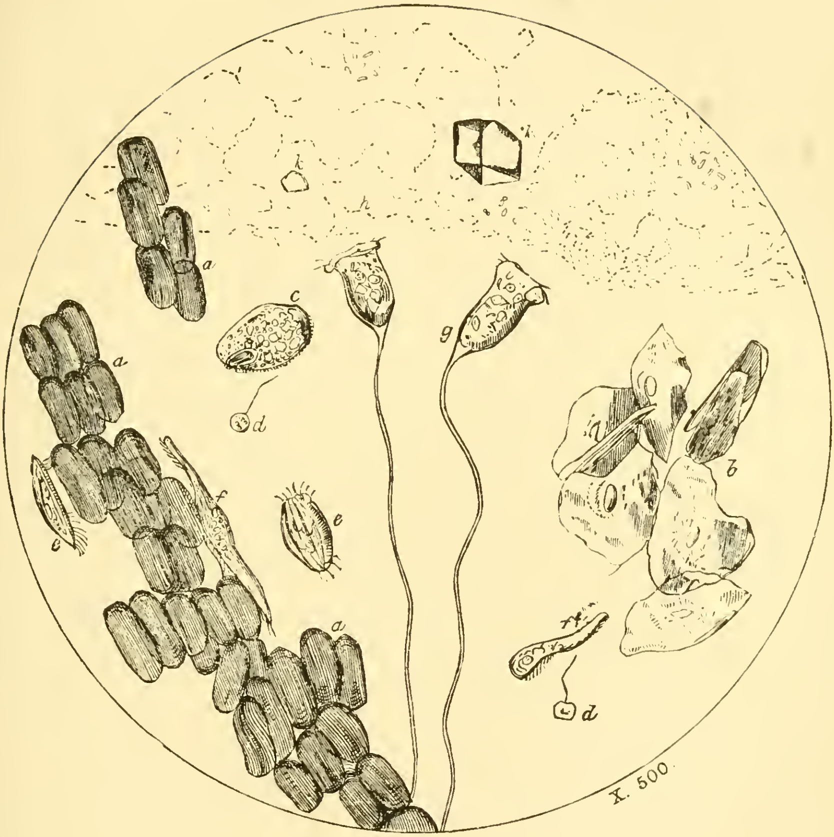


Plate IV.



REFERENCES.

a, *a*, *a*, Brown Vegetable Cells (probably Sporangial), probably disengaged gonidia of lichens (Leighton).
b, Scales of Epithelium.
c, Glaucoma Scintillans.
d, Monas Lens.
e, *e*, Aspidisca Denticulata, or Coccudina.
f, *f*, Oxytricha Gibba ; *f′* young.
g, Vorticella Convallaria.
h, Bacterium Termo in a broad sheet.
i, Localized Groups of a larger form.
k, Crystalline Particles, probably quartz

Gases.—Oxygen, nitrogen, carbon dioxide, hydrogen sulphide, and carburetted hydrogen are the most usual gases. If the three former co-exist, as is generally the case, the oxygen is usually in larger relative amount than in atmospheric air, as it often reaches 32 per cent.[1] The amounts of oxygen and carbon dioxide depend so much on varying conditions, such as the amount of exposure to the air, the growth or absence of plant life, and the presence of animals, as to render the proportions, absolute and relative, of the gases so variable, that few inferences of hygienic importance can be drawn from their determination. A lessening, however, at one part of its course, in the quantity of oxygen which a certain water is known to contain, may be useful, as pointing out that organic matter has been in the water.[2]

Thus Professor Miller found that Thames water contained the following amount of gases in C.C. per litre, in its flow down stream :—

	Kingston.	Hammersmith.	Somerset House.	Greenwich.	Woolwich.
Carbon dioxide, .	30.3	...	45.2	55.6	48.3
Oxygen, ...	7.4	4.1	1.5	.25	.25
Nitrogen, ...	15.	15.1	16.2	15.4	14.5

The stability of the nitrogen, the increase in the CO_2, and the lessening of the oxygen, are well seen. If water contain much CO_2, bubbles of the gas form on the sides of the glass in which the water is placed. So far as our knowledge extends at present, there seems to be but little information obtained by the determination of the amount of gases in water; but if it is decided to do so, we require a mercurial trough, a graduated tube-measure to be filled with mercury and inverted into the trough, a flask and a connecting tube with a bulb blown on it. The flask is filled with water and connected with the bulb-tube by an india-rubber tube, which is to be closed by a clamp. Some water is put into the bulb, and boiled; this is to expel air from the connecting tube; and when this is done, the end of the tube is put into the mercurial trough under the vessel filled with mercury, the clamp is removed from the india-rubber tube, and the water is cautiously boiled for an hour. The gases collect in the mercurial tube, and are measured (due regard being had to temperature and pressure, and the other corrections); the CO_2 is absorbed by potash, the oxygen by potassium pyrogallate, and the nitrogen is read as the residue.

As regards the CO_2, there is an objection to this method, as the heat decomposes the calcium and magnesium bicarbonates, and therefore the amount of CO_2 evolved is greater than existed in the water as free carbonic acid. On the other hand, it is impossible by heat alone to obtain all the oxygen and nitrogen.[3]

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[1] Atmospheric air, according to Bunsen's co-efficients of absorption, would dissolve in water in the proportion of 65.1 of nitrogen and 34.9 of oxygen.—Wanklyn, Water Analysis, p. 103.

[2] Up to recently Gérardin considered that the degree of oxygen (oxymétrie) was the best test of a water's purity. He has since modified this view considerably. The importance of the indication is also greatly lessened by the fact that deep well waters, of undoubted potable excellence, yield extremely little oxygen—often not more than the Thames at Woolwich.

[3] The plan of determining the oxygen by means of the sodium hydrosulphite, suggested by Schützenberger and Gérardin, is ingenious and rapid, but it has the inconvenience of requiring the reagent to be freshly prepared, as it will not keep. (See Comptes Rendus de l'Académie des Sciences; Lefort, Traité de chimie hydrologique; Annales d'Hygiène, Janvier, 1877.)

As this operation is a rather delicate one, and requires some practice, and as the information it gives, in a hygienic point of view, does not appear to be so useful as that obtained by other methods, it my be omitted except in cases where the amount of aëration is considered very important. The amount of free CO_2 can also be determined approximately by the soap solution subsequently described. Dr. Macnamara has proposed [1] a still simpler method for the examination of water in India.

Dr. Frankland has proposed a very ingenious plan for extracting the gases from water without heat. It is an application of the Sprengel pump, in which the Torricellian vacuum of a barometer is made to act as an air-pump. The gases can be extracted either at the ordinary or boiling temperature. This plan may be useful in laboratories where much water analysis is carried on, but it can hardly at present be applied by army medical officers.

Hydrogen sulphide sometimes occurs in water as a consequence of the decomposition of sulphates by organic debris, even by the cork of the bottles, the SH_2 being afterwards liberated by carbonic acid. In some mineral waters (Marienbad) hydrogen sulphide appears when *algæ* are in the water, but not without.[2]

If the gas is present in any quantity, it can be detected by the smell. Alkaline sulphides have, however, less smell. Both, even without smell, can be detected by salts of lead. A large quantity of water should be taken in an evaporating dish, and a little clear lead subacetate or acetate allowed to flow tranquilly over the surface. Black fibres of lead sulphide are formed. If lead acetate is mixed with solution of soda until the precipitate which at first forms is redissolved, a very delicate test-liquor is obtained. Solution of sodium nitro-prusside is also a delicate test, and gives a beautiful violet-purple color. As it acts only on the alkaline sulphides, a little solution of soda or ammonia must also be added to detect the free hydrogen sulphide.

Carburetted hydrogen in small quantity in water is not readily detected, but Tiemann says that warming the water to 110° Fahr. will enable the smell to detect coal-gas, when chemical reagents fail. Generally there are other impurities, especially if it be derived from gas impregnation. In larger quantity it sometimes bubbles up from the water of stagnant pools, particularly if there be much vegetable matter; and in the cases of some natural springs in petroleum districts, can be ignited.

Dissolved Solids.

The chemical examination of the dissolved matters is divided into the *qualitative* and the *quantitative.*

Qualitative Examination of Dissolved Solids.

The water may be either at once treated, or, in the case of some constituents, it should be concentrated by evaporation.

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[1] Scheme of Water Analysis for India.

[2] Archiv. für Wiss. Heilk., 1864, No. III., p. 261.

Water not Concentrated.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Reaction	*Litmus* and *turmeric* papers; usual red or brown reactions.	Usually neutral. If acid, and acidity disappears on boiling, it is due to carbonic acid. If alkaline, and alkalinity disappears on boiling, to ammonia (rare). If permanently alkaline, to sodium carbonate.
Lime	*Oxalate of ammonium.* White precipitate.	Six grains per gallon give turbidity; sixteen grains considerable precipitate.
Chlorine	*Nitrate of silver*, and *dilute nitric acid.* White precipitate becoming lead color.	One grain per gallon gives a haze; four grains per gallon give a marked turbidity; ten grains, a considerable precipitate.
Sulphuric Acid..	*Chloride of barium* and *dilute hydrochloric acid.* White precipitate.	One and a half grain of sulphate gives no precipitate until after standing; three grains give an immediate haze, and, after a time, a slight precipitate.
Nitric Acid	*Brucine* solution[1] and *pure sulphuric acid.* A pink and yellow zone.	The sulphuric acid should be poured gently down to form a layer under the mixed water and brucine solution; half a grain of nitric acid per gallon (= 0.7 per 100,000) gives a marked pink and yellow zone; or, as recommended by Nicholson, 2 C.C. of the water may be evaporated to dryness; a drop of pure sulphuric acid and a minute crystal of brucine be dropped in; .01 grain per gallon (= .0143 per 100,000) can be easily detected.
Nitrous Acid ...	*Iodide of potassium*[1] and *starch* in solution and *dilute sulphuric acid.* An immediate blue color.	Add the solution of iodide of potassium and starch, and then the acid; the blue color should be immediate; make a comparative experiment with distilled water.
	Solution of *metaphenylene-diamine* and dilute *sulphuric acid* (Griess' test)—a yellow color more or less immediate according to amount of nitrous acid.	This is a very delicate test; a yellow color will appear in the water in half an hour, if there be only one part of nitrous acid in 10,000,000 of water.
Ammonia	*Nessler's* solution.[1] A yellow color or a yellow brown precipitate.	If in small quantity, several inches in depth of water should be looked down through on a white ground.

[1] See Appendix A, vol. ii.

Water not Concentrated—Continued.

Substance sought for.	Reagents to be used, and effects.	Remarks.
Iron..........	*Red* and *yellow prussiates of potash*, and *dilute HCl.* Blue precipitate.	The red for ferrous and the yellow for ferric salts.
Hydrogen Sulphide.	A salt of *lead.* Black precipitate.	When the water is heated the smell of hydrogen sulphide may be perceptible.
Alkaline Sulphides.	*Nitroprusside of sodium.* A beautiful violet-purple color.	A black precipitate with lead, but no color with nitroprusside shows that the hydrogen sulphide is uncombined.
Oxidizable matter, including organic matter.	*Gold chloride.* Color varying from rose-pink through violet to olive; a dark violet to black precipitate.	The water, which should be neutral or feebly acid, must be boiled for twenty minutes with the gold chloride. If no nitrous acid be present, the reaction may generally be considered due to organic matter.
Do.	Note the darkening of the *silver chloride* in testing for chlorine.	Compare with a precipitate produced in a pure solution of a chloride.
Lead or Copper.[1]	*Ammonium sulphide.* Dark color, not cleared up by hydrochloric acid.	Place some water (100 C.C.) in a white dish, and stir up with a rod dipped in ammonium sulphide; wait till color produced, then add a drop or two of hydrochloric acid. If the color disappears, it is due to iron; if not, to lead or copper.[2]
Zinc..........	*Hydrogen Sulphide.* A white precipitate. If zinc be in considerable quantity, it is generally present as bicarbonate, and gradually forms a film of carbonate on the surface of the water. This film may be collected and heated on platinum foil. If a residue remain yellow when hot and white on cooling, the presence of zinc is indicated. This reaction is very delicate.[3]	This test is not available if there be iron present, should the water be alkaline. It forms, however, in perfectly neutral waters, but not in acid.

[1] Sidney Harvey (Analyst, vol. vi., p. 146) recommends small crystals of potassium bichromate. According to him $\frac{1}{10}$ of a grain per gallon gives an immediate turbidity, $\frac{1}{20}$ after fifteen minutes, and $\frac{1}{50}$ after thirty minutes.

[2] Wanklyn.

[3] Frankland, Water Analysis, 1880, p. 44.

Water Concentrated to $\frac{1}{50}$th (in a porcelain dish).

Substance sought for.	Reagents to be used, and effects.	Remarks.
Magnesia	*Oxalate of ammonium* to precipitate lime, then after filtration a few drops of *phosphate of sodium*, of *chloride of ammonium*, and of *liq. ammoniæ*. A crystalline precipitate in twenty-four hours.	A precipitate forms in twenty-four hours, and is the triple phosphate either in the shape of prisms or in feathery crystals.
Phosphoric Acid.	*Molybdate of ammonium* and *dilute nitric acid*. A well-marked yellow color, and on standing a precipitate.	Add the nitric acid, and stir with a glass rod, then add twice the quantity of molybdate and boil.
Nitric Acid	*Brucine* test.	If the nitric acid is in small quantity, it may not be detected in the unconcentrated water.
Silicic Acid.....	Evaporate to dryness, moisten with *strong hydrochloric acid;* after standing, add boiling distilled water; pour off fluid; dry, ignite; repeat the treatment with hydrochloric acid and water; dry, ignite again, and the residue is silica, or silicate of aluminium.	The residue may be weighed, and thus the silica determined quantitatively. A little clay or oxide of iron will be sometimes mixed with it.
Lead or Copper.	As before.	If quantity be very small.
Arsenic	*Marsh's* or *Reinsch's* tests.	Water should be rendered alkaline with *sodium carbonate* before concentration, then acidulated with *hydrochloric acid.*
Zinc	Evaporate to dryness; treat residue with *caustic potash* or *ammonia*, filter and test filtrate with *hydrogen sulphide;* a white precipitate falls.	This is necessary if the quantity be small, or if iron be present. If a film of carbonate forms on concentration, it may be tested on platinum foil, as before described.

Inferences from the Qualitative Tests.

Sometimes no time can be given for quantitative determinations, and the qualitative tests are the only means available by which the question so constantly put, whether a water is wholesome or not, can be in some degree answered.[1]

If chlorine be present in considerable quantity, it either comes from strata containing chloride of sodium or calcium, from impregnation of sea-

[1] Kubel and Tiemann rely very greatly on the qualitative tests.

water, or from admixture of liquid excreta of men and animals. In the first case the water is often also alkaline, from sodium carbonate ; there is an absence, or nearly so, of oxidized organic matters, as indicated by nitric and nitrous acids and ammonia, and of organic matter ; there is often much sulphuric acid. These characters are common in deep well waters. If it be from calcium chloride, there is a large precipitate with ammonium, oxalate after boiling. If the chlorine be from impregnation with sea-water, it is often in very large quantity ; there is much magnesia, and little evidence of oxidized products from organic matters. If from sewage, the chlorine is marked, and there is coincident evidence of nitric and nitrous acids and ammonia, and sometimes phosphoric acid ; and if the contamination be recent, of oxidizable organic matters. A stream fouled by animals or excreta may thus show at different times of the same day different amounts of chlorine, and this, in the absence of rain, will indicate contamination.

Ammonia is almost always present in very small quantity, but if it be in large enough amount to be detected without distillation it is suspicious. If nitrates, etc., be also present, it is likely to be from animal substances, excreta, etc. Nitrates and nitrites indicate previously existing organic matters, probably animal, such as excreta, remains of animals, etc.;[1] but nitrates may also arise from vegetable matter, although this is probably less usual. If nitrites largely exist, it is generally supposed that the contamination is recent. The coincidence of easily oxidized organic matters, of ammonia, and of chlorine in some quantity, would be in favor of an animal origin. If a water gives the test of nitric acid, but not nitrous acid, and very little ammonia, either potassium, sodium, or calcium nitrate is present, derived from soil impregnated with animal substances at some anterior date. If nitrites are present at first, and after a few days disappear, this arises from continued oxidation into nitrates ; if nitrates disappear, it seems probable this is caused by the action of *bacteria*, or other low forms of life. Sometimes in such a case nitrites may be formed from the nitrates. Phosphoric acid, if in any marked quantity, indicates origin from phosphatic strata (which is uncommon) or sewage impregnation. Wanklyn has ridiculed the idea of phosphoric acid being present in any appreciable quantity in water, if (as is almost always the case) lime be also present. But, independent of the fact that the reaction of phosphoric acid is obtained in water, Hehner[2] has clearly shown that phosphoric acid does exist in appreciable quantity as phosphates, especially in polluted waters. Lime in large quantity indicates calcium carbonate if boiling removes the lime, sulphate or chloride or nitrate if boiling has little effect. Testing for calcium carbonate is important in connection with purification with alum. Sulphuric acid in large quantity, with little lime, indicates sulphate of sodium, and usually much chloride and carbonate of sodium are also present, and on evaporation the water is alkaline. Large evidence of nitric acid, with little evidence of organic matter, indicates old contamination ; if the organic matter be large, and especially if there be nitrous acid as well as nitric present, the impregnation is recent. It may also indicate the absence of the nitrifying ferment from the water.

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[1] Dr. Frankland has considered these substances as the representatives of "previous sewage contamination." In many cases they are so, but it cannot be held that they are always so ; any nitrogenous substance, quite apart from sewage, may furnish them, so that the phrase has been objected to, and is better avoided.

[2] Analyst, vol. v., p. 135.

Tabular View of Inferences to be Drawn from Qualitative Examination.

Chlorine.	Oxidizable matter by Gold Chloride or Silver Chloride.	Nitrates.	Nitrites.	Ammonia.	Phosphates.	Sulphates.	Classification of Water.	Remarks.
Slight..	Slight ...	Nil	Nil	Nil	Nil	Trace ..	Good...	A perfectly pure water.
Marked.	Nil or trace.	Nil	Nil	Marked..	Present.	Trace ..	Good...	A good water, probably from a deep well.
Marked.	Slight ...	Marked ..	Nil or trace.	Trace...	Trace ..	Trace ..	Usable..	Probably old animal contamination.
Large ..	Slight ...	Nil or trace.	Nil	Nil	Nil or trace.	Marked.	Usable..	Probably some contamination with sea-water.
Slight..	Well-marked.	Marked to large.	Nil	Nil	Nil or trace.	Nil or trace.	Usable..	Probably vegetable impurity: peat?
Marked.	Nil or trace.	Marked ..	Nil or trace.	Marked..	Marked.	Marked.	Suspicious.	Probably a shallow well, contaminated with urine.
Slight..	Marked..	Present ..	Present.	Marked..	Trace ..	Trace ..	Impure.	Probably water contaminated with sewer gases.
Marked.	Large....	Marked ..	Marked.	Marked..	Marked.	Marked.	Impure.	Water contaminated with sewage.

To the above qualitative tests would, of course, be added the physical characters, which would to some considerable extent influence the conclusions to be drawn. When possible, the microscopic appearances ought also to be carefully noted, as the presence of such substances as epithelium, house refuse, etc., will sometimes justify us in condemning a water which may appear chemically only suspicious.

A water containing in appreciable quantity any metal (except iron), other than the alkaline and earthy metals, is to be condemned.

A water containing any gas, other than oxygen, nitrogen, or CO_2, is to be considered suspicious, and not to be used without boiling or filtration, or both.

Quantitative Examination of Dissolved Solids.

The discrepancies which are sometimes found in the consecutive analyses, or in analyses by two observers of the same water, probably often arise from the difficulty of always separating the suspended matters. Consequently two samples, apparently similar, may in reality contain variable quantities of suspended matters which affect the determination of the solids, or influence other tests.

To avoid this source of fallacy, if the water be sedimentous, the portion to be examined for solids should be placed in a well-stoppered bottle in a dark place for twenty-four or forty-eight hours, until all sediment has subsided, and the clear water should be then siphoned off. If the sediment is too fine to subside, the water must be filtered through paper (previously well washed with weak hydrochloric acid, and then with distilled water, and then dried), but if possible filtration should be avoided.

Of the solids in water, some are mineral, and derived from the mineral

constituents of the soil, such as lime, magnesia, and part of the chlorine, and of the sulphuric, carbonic, and silicic acids ; others are also inorganic, but are derived from the remains of animals or vegetables, by oxidation or solution, or from the atmosphere, such as ammonia, nitric acid, nitrous acid, some of the chlorine, and of the sulphuric and phosphoric acids. Other constituents, derived from numerous sources, are vegetable or animal matters, which are usually unstable, and are undergoing disintegration and oxidation. They may be nitrogenous or not. The composition of these substances is doubtless extremely various ; the determination of the total quantity is difficult ; the separation of the different kinds from each other, at present, impossible.

The methods by which the quantity of this organic matter (to use its familiar name) can be expressed have been lately much debated, and even now there is no general agreement ;[1] nor, at present, is there any plan by

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[1] The following plans have been tried at successive times :—

1. The estimation by ignition of the dried solids. However useful ignition is as indicating the presence of nitrites, nitrates, or organic matter, the results are very uncertain as regards quantity, owing to the loss of hygroscopic water, the decomposition of carbonates, and errors arising in recarbonating, the loss of nitrites and nitrates, and in some cases of chlorine, as well as the destruction of organic matter. Hence "substances driven off by heat," or "volatile substances," is not an equivalent expression for "organic matters."

2. Precipitation by perchloride of iron, weighing, incinerating, and weighing again. The difficulty here is that all the organic matter is not precipitated, and other mineral substances may be.

3. The determination of the nitrogen and carbon in the organic substances. This is the plan proposed by Dr. Frankland, who determines the nitrogen in the ammonia, nitric and nitrous acids, which may be present, and also that in organic combination, and in this way gets at the nitrogen, which must have formed part of the organic matter ("organic nitrogen"). In the same way the carbon existing other than in the shape of carbonic acid is determined ("organic carbon"). He has proposed a most ingenious and beautiful process, the most recent and best account of which is contained in his Water Analysis for Sanitary Purposes, p. 59, 1880. This plan requires so much apparatus, time, and skill, as to be quite beyond the reach of medical officers, and it would also appear that in the hands of even very able chemists it gives contradictory results ; the quantities are in fact so small, and the chances of error so repeated, that in its present form this really beautiful plan seems not adapted for hygienic water analysis. It is also difficult to know what construction should be put on the results ; a water containing much non-nitrogenous organic matter may give a very much larger amount of "organic carbon" than a water containing a much smaller amount of nitrogenous matter, and yet be much less hurtful.

4. The determination of the nitrogen of the organic matters (as ammonia) by means of alkaline permanganate of potassium ("albuminoid ammonia"), after all ammonia existing as such in the water has been got rid of. This plan, proposed by Wanklyn and Chapman, has the merit of simplicity and rapidity. It has been objected to by Frankland on the ground that the whole of the nitrogen is not obtained. There is no doubt of this; but Wanklyn affirms that the quantity obtained is constant, and therefore comparison between different waters can be instituted. Thudichum and Dupré, in their work on Wine (p. 262), state that they find the albuminoid ammonia process so accurate for albumen in wine, that they use it in preference to other methods. It must be confessed that this point has not been probed to the bottom, and that especially the relation of the "albuminoid ammonia" to disease produced by the water has not been yet made out. The "albuminoid ammonia" of pure potable water has been simply taken as a standard, and the wholesomeness of other waters judged of by reference simply to this. But at the present time it is the most convenient process we have, and (with some reservation as to the precise inferences to be drawn from it) it has been pretty generally adopted.

5. Two other processes, that of Dittmar and Robinson, and that of Dupré and Hake, are described in Frankland's Water Analysis, but neither seems adapted for the use of medical officers.

6. Estimation of the organic matter in terms of the oxygen required to oxidize it,

which dissolved vegetable may be distinguished from animal matter, except by reference to the microscopic characters of the sediment, to the source of the water, and the coincident inorganic substances.

The quantitative processes which appear, in a hygienic sense, to be most useful are as follow :—

Determination of—

1. *Dissolved solids.* (*a*) Total. (*b*) Fixed. (*c*) Volatile.
2. *Chlorine.*
3. *Hardness.* (*a*) Total. (*b*) Fixed. (*c*) Removable.
4. *Free or saline ammonia and nitrogenous organic matter.*
   (*a*) *Free* ammonia.
   (*b*) *Albuminoid* ammonia.
5. *Oxidizable matter and products of organic oxidation.*
   (*a*) In terms of *oxygen* required for *total oxidizable matter.*
   (*b*) In terms of *oxygen* required for *organic matter* only.
   (*c*) *Nitrous acid.*
   (*d*) *Nitric acid.*
6. *Phosphoric acid* in phosphates.
7. *Sulphuric acid, silica, iron,* and the *alkaline carbonates,* may be determined, but are seldom required.

The statement of results is usually given in this country in grains per gallon, or in parts in 100,000 ; or it may be given in grammes per litre, which is the same as parts per 1,000, and by shifting the decimal point to the right, parts per 10,000, 100,000, or per 1,000,000 are obtained.[1] It is much to be desired that one uniform mode should be definitively adopted, in order to avoid the confusion which at present undoubtedly exists in this country.

1. DETERMINATION OF THE DISSOLVED SOLIDS.

(*a*) *Total solids.*—The remark already made about suspended matters must be attended to ; if possible, obtain a clear water by subsidence rather than by filtering through paper. The solids are determined by evaporation. If very good scales are available, 200 C.C. of the water are sufficient,[2] if the scales are inferior, 500 or 1,000 C.C. of the water must be taken ; then evaporate to dryness with a moderate heat, taking care that the water

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the permanganate of potassium being the oxidizing agent. This process (originally proposed by Forchammer of Copenhagen) has been much used and much objected to, and some chemists have now given it up. It gives, certainly, only an approximation, requires care, and will only indicate the organic matter capable of oxidation. Yet it gives really useful information, as it often adds additional evidence to Wanklyn's method, and gives some indication as to the old or recent origin of nitric acid, and is easy of application. The objections urged against it by Frankland have been recently modified, and it is acknowledged as a process of value, when properly applied. It would be very undesirable to discontinue it ; and in those cases where, from want of apparatus, the distillation necessary for Wanklyn and Chapman's method cannot be done, it is at present absolutely essential. Kubel and Tiemann reject both Frankland's and Wanklyn's methods as untrustworthy, and trust to modifications of the permanganate process. For further discussion of the subject, see under "Organic Matter," later on.

[1] Grammes per litre are converted into grains per gallon by multiplying by 70. Milligrammes per litre, if multiplied by .07, are brought into grains per gallon. Grains per gallon are converted into parts per 100,000 by dividing by .7 ; parts per 100,000 are brought into grains per gallon by multiplying by .7.

For equivalents of the metrical weights, see Appendix B, vol. ii.

[2] Wanklyn recommends a "miniature gallon" of 70 C.Cs., which, he says, evaporates in one hour. This is too small a quantity to work on. Becker of Rotterdam has introduced very good scales at a low price.

does not boil, else there may be loss from spurting. If the smaller quantity be taken, the whole evaporating may be conducted in one vessel (of platinum if possible) ; but if the larger amount must be used, the evaporation should be commenced in a large evaporating dish, and the concentrated water and deposit, if any, transferred into a small weighed crucible. The transference demands great care, so that none of the solids shall remain incrusted in the evaporating dish. All the contents of the large dish being transferred, evaporate to complete dryness in an air, water, or steam bath, at 212° Fahr. (100° C.). Weigh as soon as the capsule is cold, as the dried mass may be hygroscopic. It may be necessary to replace it in the bath and weigh again after an interval of half an hour. If there is no material difference the drying is completed.

Professor Wanklyn advises a very simple form of steam bath. A common two-gallon tin can is taken, a perforated cork fitted in the mouth, and a funnel passed through the perforation ; the crucible is placed in the funnel, a little roll of paper being placed between the funnel and crucible to let the steam pass. Water is boiled in the tin can.

Bischof's bird-fountain apparatus is very convenient for evaporation.

Dr. Frankland recommends that the heat shall not be carried above 212° Fahr. (100° C.), while some chemists advise a heat of over 300° (148° C.). At 212° (100° C.), sufficiently complete drying can be obtained by prolonged exposure, whilst at the higher temperature we risk destroying the organic matter.

The S.P.A. recommend evaporating first in a water bath, then drying the residue at 220° Fahr. (104.5° C.), and finally cooling under a desiccator.[1] It would be well not to exceed 220° Fahr. (104.5° C.).

The determination of the total solids is an important point, and should be carefully done. It gives a control over the other quantitative determinations, and if erroneous may make the other conclusions wrong.

(*b*) *Fixed solids.*—Incinerate the dried solids at as low a heat as possible ; watch the process, and note if there be much blackening, or if any fumes can be seen, or any smell be perceived as of burnt horn. A piece of filtering paper dipped in solution of potassium iodide and starch, and then dried, or a piece of ozone paper, should be held over the crucible to detect any nitric oxide which may be given off.

(*c*) *Volatile solids.*—The loss on ignition may be stated as "volatile substances." It consists of destructible organic matters, nitrates, nitrites, ammoniacal salts, combined water, combined carbonic acid,[2] and sometimes chlorides. The variableness of the composition of the "volatile substances" has led to the disuse of the process by ignition as too uncertain. Combined with other evidence it gives, however, some useful indications. The incinerated solids may be examined for silica and iron, as hereafter noted.

The statement of the results may be given in various ways, as before mentioned, but the ratios most used nowadays are parts in 100,000 (equal to *centigrammes* per *litre*) or *grains* in a *gallon* (equal to parts in 70,000).

Example: 1. *Total solids.*—200 C.Cs. dried as described :

Weight of dish and residue, . . .	19.27 grammes.
" of dish alone, ...	19.23 "
Difference, . .	0.04

being grammes of total solids in 200 C.Cs. of water.

[1] Tiemann recommends 150° to 180° C., equal to 342° to 354° F.

[2] This may be partly restored by adding a little saturated solution of ammonium carbonate, and then drying and driving off the excess of ammonia.

To bring to grammes per litre:

$$0.04 \times 5 = 0.20 = \text{grammes per litre.}$$

Shifting the decimal point two places to the right, we have 20 centigrammes per litre, or 20 parts in 100,000.

To bring to grains per gallon:

$$20 \times 0.7 = 14.0 \text{ grains per gallon.}$$

2. *Fixed solids.*—The above residue is incinerated, and the CO_2 restored to the earthy carbonates if required.

Weight of incinerated residue and dish,	19.26
" of dish alone, ...	19.23
Difference, being grammes of fixed solids in 200 C.C. of water, ...	0.03

$$0.03 \times 5 = 0.15 \text{ per litre} = 15 \text{ parts per } 100{,}000.$$

$$15. \times .07 = 10.5 \text{ grains per gallon.}$$

3. *Volatile solids:*

		Parts per 100,000.	Grains per gallon.
Total solids,	=	20.0	14.0
Fixed "	=	15.0	10.5
Difference, being volatile solids,		5.0	3.5

2. DETERMINATION OF CHLORINE.

Chlorine may be determined very rapidly by the volumetric method. For this purpose a solution of potassium mono-chromate and a standard solution of silver nitrate are required.[1]

Take 100 C.C. of the water to be examined; place it in a glass vessel standing on a piece of white paper; add 1 C.C. of potassium mono-chromate solution, which must be free from chlorine, drop in the silver nitrate from the burette, and stir after each addition. The red silver chromate which is at first formed will disappear as long as any chlorine is present. Stop directly the least red tint is permanent. Neither the solution of silver nor the water must be acid; if the latter is acid, it should be neutralized with a little precipitated carbonate of calcium. The number of C.Cs. of silver solution used gives exactly the parts of chlorine per 100,000 of water. To bring to grains per gallon, multiply by 0.7.

Example.—In 100 C.C. of water, 1 C.C. of potassium mono-chromate and 1.5 C.C. of silver solution gives a permanent red tint, therefore the water contains 1.5 parts per 100,000 of chlorine; $1.5 \times 0.7 = 1.05$ grains per gallon.

3. HARDNESS.

Clark's very useful soap test offers a ready mode of determining this in a manner quite sufficient for hygienic and economic purposes. The processes with the soap test may be divided into two headings.

I. The determination of the aggregate earthy salts, and free carbonic acid, as expressed by the term *total hardness.* The aggregate determination can be divided into two kinds of hardness, viz., that which is unaffected and that which is affected by boiling, and these are termed the *permanent* and the *removable hardness.*

[1] For the preparation of the solutions, see Appendix A, vol. ii.

II. The determination of the amount of certain constituents, as the lime, magnesia, sulphuric acid, and free carbonic acid. These results are only approximative, especially in the case of the magnesia; but they are very useful, as they give us enough information for hygienic purposes, and are done in a very short time.

Apparatus and Reagent required for the Soap Test.—Burette divided into tenths of a cubic centimetre; measure of 50 C.C. or 100 C.C.; stoppered bottles of about 100 C.Cs. (4 ounces) capacity. Standard soap solution, 1 C.C. = 2.5 milligrammes of calcium carbonate.[1]

Rationale of the Process.—When an alkaline oleate is mixed with pure water, a lather is given almost immediately; but if lime, magnesia, iron, baryta, alumina, or other substances of this kind be present, oleates of these bases are formed, and no lather is given until the earthy bases are thrown down. Free (but not combined) carbonic acid prevents the lather. The soap combines in equivalent proportions with these bases, so that if the soap solution be graduated by a solution of known strength of any kind, it will be of equivalent strength for corresponding solutions of other bases. There are, however, one or two points which render the method less certain. One of these is, that, in the case of magnesia, there is a tendency to form double salts (Playfair and Campbell), so that the determination of magnesia is never so accurate as in the cases of lime or baryta. Carbonic acid appears to unite in equivalent proportions when it is passed through the soap solution; but if it be diffused in water, and then shaken up with the soap solution, two equivalents of the acid unite with one of soap.

To avoid the repetition of the term "tenth of a centimetre," it will be convenient to call each tenth of a centimetre *one measure*, and this precipitates 0.25 of a milligramme of calcium carbonate.[2]

Processes with the Soap Test.

(*a*) *Determination of the total Hardness of the Water.*—Take 50 C.C. of the water; put it in a small stoppered bottle, and add the soap solution from the burette; shaking it strongly after each addition until a thin uniform beady lather spreads over the whole surface without any break. If the lather is permanent for five minutes, the process is complete; if it breaks before that time, add a drop or two more of the solution, and so proceed until a lather be obtained that is permanent for five minutes.

Then read off the number of *measures* of soap solution used.

From the total number of *measures* (or *tenths* of a centimetre) used, deduct 2, as that amount is necessary to give a lather with 50 C.C. of the purest water, and this deduction has to be made in all the processes. The soap solution which has been used indicates the hardness due to all the ingredients which can act on it; in most drinking waters these are only lime and magnesian salts, iron, and free carbonic acid.

The amount of this total hardness is, for convenience, usually expressed in this country in the manner proposed by Dr. Clark, *i.e.*, though dependent on various causes, it is expressed as equivalent to so much calcium carbonate per gallon, and in Clark's scale 1 grain of calcium carbonate per gallon is called 1 degree of hardness.

This is done as follows:—

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[1] The soap solution here recommended was suggested by Surgeon-Major Nicholson, formerly R.A., see Appendix A, vol. ii.

[2] A weaker solution is often used, see Appendix A, vol. ii.

Each 0.1 C.C., or in other words, each *measure*, of our soap solution corresponds to .25 mgm. of calcium carbonate. Multiply this co-efficient by the number of measures of soap solution used, and the result is the hardness of 50 C.C. of water expressed as calcium carbonate. Then, as we have acted on one-twentieth of a litre, multiply by 20 to give the amount per litre, and then by 0.07 to bring the amount to grains per gallon.

Example.—A lather was given with 3.2 C.C., or 32 measures of the soap solution. $(32-2) \times .25 \times 20 \times 0.07 = 10.5$ grains of calcium carbonate per gallon.

Hardness expressed as calcium carbonate $= 10.5°$ Clark's scale:

(viz., $1° = 1$ grain of $CaCO_3$ per gallon.)

The same result (viz., grains per gallon) is obtained if the number of measures (less 2) is multiplied by .35; thus, 32 measures were used:

$$(32-2) \times .35 = 10.5.$$

The hardness is also often expressed on the metrical system, as parts in 100,000. This is easily done by taking one-half of the measures of soap used, after deducting 2 for the lather. Thus, in the previous example, 32 measures were used:—deduct 2, there remain 30; $30 \div 2 = 15$ degrees of hardness on the metrical scale, or per 100,000.

To convert metrical degrees into Clark's scale, multiply by 0.7; to convert Clark's scale into metrical degrees, divide by 0.7.

If the hardness of the water exceeds 40 measures of the soap solution, 25 C.C. of water only should be taken, and 25 C.C. of distilled water added.

The result must then be multiplied by 2.

(*b*) *The Permanent or Fixed Hardness.*—Boil a known quantity in a flask briskly for half an hour, and replace the loss by distilled water from time to time; allow it to cool down to 60° Fahr. (15.5° C.) in the vessel, which should be corked, and determine hardness in 50 C.C. If distilled water is not procurable, then boil 200 C.C. down to 100; take half the remainder = (100 of unboiled water) and determine hardness.[1] After deducting 2 measures, divide the number of measures by 2 for the hardness of 50 C.C., and calculate as usual.

By boiling, all carbonic acid is driven off; all calcium carbonate, except a small quantity, is thrown down; the calcium sulphate and chloride are not affected if the evaporation is not carried too far; the magnesium carbonate at first thrown down is re-dissolved as the water cools. If iron is present, most of it is thrown down.

Example.—Before boiling, 32 measures, and after boiling 13 measures, of the soap solution were used:

$$(13-2) \times .25 \times 20 \times 0.07 = 3.85 \text{ degrees of Clark's scale.}$$
$$13 - 2\ (= 11) \div 2 = 5.5 \text{ degrees of the metrical scale.}$$

(*c*) *Removable Hardness.*—The difference between the total and the permanent hardness is the temporary or removable hardness, which in the example would be $10.5 - 3.85 = 6.65$ degrees of Clark's scale, and $15 - 5.5 = 9.5$ degrees of the metrical scale.

The amount of permanent hardness is very important, as it chiefly represents the most objectionable earthy salts—viz., calcium sulphate and chloride, and the magnesian salts. The greater the permanent hardness, the

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[1] If there is much fixed hardness this process is hardly available.

more objectionable is the water. The permanent hardness of a good water should not, if possible, be greater than 3° or 4° of Clark's scale.

The determination, then, of

1. The *total* hardness,
2. The *permanent* or *fixed* hardness,
3. The *temporary* or *removable* hardness,

will enable us to speak positively as to the hygienic characters of a water, so far as earthy salts are concerned.[1]

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[1] *Determination of Certain Constituents by Soap.*—In many cases the analysis must end with the above processes; but it may be desirable to carry it further, and to determine the amount of some ingredients; for example, lime, magnesia, sulphuric acid, carbonic acid.

An approximate estimate can be given of several of these ingredients by the soap test, which is sufficient for hygienic purposes; and any one who has learned to determine properly the hardness of a water will be able to carry on the process into finer details.

Lime by the Soap Test.—Messrs. Boutron and Boudet have proposed, after determination of total hardness, to precipitate the lime by ammonium oxalate, and then to determine the hardness again. The difference will be owing to lime removed. The difficulty here is to add enough, and not too much, of ammonium oxalate, which itself in excess gives hardness.

The best way to perform this process is to have a perfectly concentrated clear solution of ammonium oxalate, and to add to 50 C.C. of water 1 drop for every 4 measures of soap solution used; then in other bottles, to add respectively, 1, 2, and 3 drops more. Then determine hardness of all the bottles, and select the result which gives the least hardness. In this way we can hit on the bottle which contains enough, but not too much ammonium oxalate. The water need not be filtered, but it should be allowed to stand at least for three or four hours, or, better still, twenty-four hours, before the hardness is taken.

Then multiply the difference between the total hardness and the hardness after the addition of the oxalate by the co-efficient for lime; this is .14 of a milligramme, as each measure of the soap solution is equivalent to this amount of lime.

Example.—Total hardness	32
After lime precipitated	10
Difference	22

22 measures $\times .14 \times 2 = 6.16$ parts of lime per 100,000, and $6.16 \times 0.7 = 4.312$ grains per gallon. Or multiply the number of measures by 0.28, this gives parts per 100,000; or by .196, the result is grains per gallon. If carefully done, this result will be near the truth.

Magnesia by the Soap Test.—Boutron and Boudet propose to determine the magnesia by boiling the water from which the lime has been thrown down. All usual elements of hardness, except the magnesia, are thus got rid of. This is by no means so accurate a process as that of the lime; the lather is formed much less perfectly and sharply, and in addition the constitution of the magnesia and soap compound is variable. The result must be considered as quite approximative, but may sometimes be rendered more accurate by diluting with distilled water.

Take 200 C.C. of water; add to it the number of drops of solution of ammonium oxalate known to be sufficient by the lime experiment; allow to stand for twenty-four hours; filter, boil for half an hour, replace loss by distilled water; allow to cool in the vessel, which should be well corked, and determine hardness in 50 C.C.

As the lime has been thrown down and all iron removed, and carbonic acid driven off, the hardness is owing to magnesian salts of some kind.

Calculate as magnesia, the co-efficient of which, for each measure of soap solution, is .1, or, as magnesium, the co-efficient of which is .06.

Example.—Hardness, after driving off carbonic acid by boiling and precipitating lime = 7

$(7-2) \times .1 \times 2 = 1.0$ part of magnesia per 100,000, $1.0 \times 0.7 = 0.7$ grain per gallon.

Or multiply the number of measures by 0.2, the result is parts per 100,000: or by .14, the result is grains per gallon.

4. DETERMINATION OF THE ORGANIC MATTERS AND THEIR PRODUCTS IN WATER.

As already stated, the determination of organic matter in water is difficult, and many processes have been proposed. Some are obviously out of the question for medical officers, save in exceptional circumstances.

Although this result is approximative, it is really nearer the truth than the determination by weighing in the hands of a beginner.

Free Carbonic Acid by the Soap Test.—In order to get rid of the fallacy from free carbonic acid acting on the soap, Clark recommended that the water should be well shaken in a bottle, so as to disengage some of the CO_2, and then that the air should be sucked out. But this does not entirely remove the carbonic acid.

By the soap test the free carbonic acid can be determined in the following way:—Throw down all the lime carefully by ammonium oxalate, without adding an excess, and determine the hardness in 50 C.C. as usual. The hardness will be owing to magnesian salts, iron, if it exists (or alumina or baryta in mineral waters), and carbonic acid. If now, the water, freed from lime, be boiled, and the loss of water replaced by distilled water, the carbonic acid will be driven off. The hardness should be then again determined. The difference between the first and second trials will (if no iron exist in the water) give the amount of soap solution which had been previously acted on by the carbonic acid.

Example.—1. Total magnesian and carbonic acid hardness..	=	12	measures.
2. Magnesian hardness	=	7	"
Carbonic acid hardness	=	5	"

1 measure of soap sol. corresponds to .22 milligramme carbonic acid. Therefore,

$$.22 \times 5 \times 20 \times 0.07 = 1.54 \text{ grain per gallon.}$$

As 2.116 cubic inches weigh one grain, multiply the number of grains by 2.116 to bring into cubic inches per gallon.

$$1.54 \times 2.116 = 3.25 \text{ cubic inches.}$$

Or, to shorten the calculation, multiply the number of measures of soap solution by .65; the result is the amount of cubic inches per gallon.

$$5 \times .65 = 3.25 \text{ cubic inches per gallon.}$$

To state the result in the metrical system, multiply the measures of soap by 0.233; this gives the volumes of CO_2 in 100 volumes of the water; or, multiply by 233, which gives the volumes in 100,000 vols. of water.

If much iron exists in the boiled water, it must be determined, and its amount deducted; one measure of soap solution corresponds to .14 milligramme of iron (Fe).

Determination of Lime and Magnesia by Weight.

It may be desired to determine the lime and magnesia by weight, and the following processes can then be used:

Lime by Weight.—Take a known quantity of water; add ammonium oxalate, and then ammonia enough to give an ammoniacal smell. Allow precipitate thoroughly to subside, and then wash by decantation, or by throwing the precipitate on a small filter of Swedish paper, the weight of the ash of which is known. Decantation is recommended. If a filter is used, wash precipitate on filter; dry; scrape precipitate from filter, and place in a platinum crucible; burn filter to an ash, by holding it in a strong gas flame, and place it also in the crucible. Heat the crucible to gentle redness for fifteen minutes, moisten with a little water, and test with turmeric paper. If no reaction is given, the process is done. If the paper is browned (showing presence of caustic lime), recarbonate with ammonium carbonate, drive off excess of ammonia, dry, and weigh.

The substance weighed is calcium carbonate, multiply by .56, and the result is lime.

Mohr's plan might also be used, viz., precipitation of the lime in an ammoniacal solution by standard oxalic acid, and then titration of the excess of the latter by permanganate.

Magnesia by Weight.—Take the water from which the lime has been thrown down; evaporate to a small bulk; filter if there be turbidity; add solution of ammonium chloride, and ammonia to slight excess; then add a solution of sodium phosphate;

Those, therefore, are described here which are not only likely to give sufficient information for hygienic purposes, but also to be within the range, for the most part, of the medical officer's appliances.

The analysis may be considered under two heads—

(A) The determination of *nitrogenous organic matters* and their products.

(B) The determination of *oxidizable organic matter*, probably chiefly *non-nitrogenous.*

(A) Includes—

(*a*) The determination of the *free, saline,* or *combined ammonia.*
(*b*) " of the (so-called) *albuminoid ammonia.*
(*c*) " of the *nitric acid.*
(*d*) " of the *nitrous acid.*

(B) Includes—

(*e*) The determination of the *oxidizable organic matter* by the permanganate processes.

(A) *Determination of the Nitrogenous Organic Matters and their Products.*

Determination of the Free and Albuminoid Ammonia.—For this analysis we require[1]—1. A standard solution of ammonium chloride, 1 C.C. of which = 0.01 of a milligramme of ammonia (NH_3); 2. Nessler's solution

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stir with a glass rod; set aside for twelve hours; throw precipitate on a filter, carefully detaching it from the sides of the glass; wash with ammoniacal water; dry; incinerate in an intense heat; weigh, taking care to deduct the ash of the filter known by previous experiment. The substance is magnesium pyrophosphate; multiply by .36036 to get the amount of magnesia.

Sulphuric Acid by Weight.—Take a known quantity of the water (500 to 1,000 C.C.), acidify with hydrochloric acid and evaporate, but not so far as to run any risk of throwing down sulphate of calcium; filter; and then add chloride of barium; allow to stand, and wash the precipitate by decantation; dry; weigh; multiply precipitate by .34305 to get the amount of sulphuric anhydride (SO_3) or by .411, if it is wished to calculate it as SO_4.

Sulphuric Acid by Soap Test.—This plan was proposed by Boutron and Boudet, and is briefly as follows:—The hardness of the water being known, 50 C.C. of the standard barytic solution (.26 gramme per litre) are added to 50 C.C. of water, and the mixture is allowed to stand for twenty-four hours. The hardness (supposing no SO_4 were present) would be exactly equal to the original hardness of the water and of the barytic solution combined. But SO_4 being present, barium sulphate is precipitated, and there is a loss of hardness. Each degree of loss equals .24 mgm. of sulphur tetroxide (SO_4).

Example.—Original hardness	32
50 C.C. barytic solution	22
	54
After precipitation	45
Difference	9

$.24 \times 9 \times 2 = 4.32$ parts per 100,000; $4.32 \times 0.7 = 3.02$ grains per gallon.

Usually this process gives good results. Occasionally, from some cause which is not clear, the barium sulphate does not precipitate. This does not depend on the amount of sulphuric acid. The ease with which this process is done renders it useful. The barytic solution is only strong enough to precipitate 6.72 grains of sulphuric acid (SO_4) per gallon, so that half the water only must be taken, or less, if the sulphuric acid be evidently in large amount.

Short factors: for $SO_3 = 0.280$, for $SO_4 = 0.336$ to state as grains per gallon; for $SO_3 = 0.40$, for $SO_4 = 0.48$ to state as parts per 100,000.

[1] For these solutions, see Appendix A, vol. ii.

as a reagent for the detection of ammonia; 3. A solution of potassium permanganate and caustic potash; 4. Pure distilled water.

(*a*) *Free Ammonia.*

Place in a retort 250 C.C. of the water to be examined. Attach the retort to a Liebig's condenser, and distil off about 130 C.C.; collect 1 C.C. more of the distillate, and test it with a few drops of Nessler, to see if any ammonia is still coming over; if so, the distillation may be continued longer. Carefully measure the amount of distillate; test a little with Nessler's solution in a test-tube; and, if the color be not too dark, take 100 C.C. of the distillate and put it into a cylindrical glass vessel, placed upon a piece of white paper. Add to it 1½ C.C. of Nessler. Pour into another similar cylinder as many C.C. of the standard ammonium chloride solution as may be thought necessary (practice soon shows the amount), and fill up to 100 C.C. with pure distilled water: drop in 1½ C.C. of Nessler. If the colors correspond after three to five minutes, the process is finished, and the amount of ammonium chloride used is read off. If the colors are not the same, add a little more ammonium chloride so long as no haze shows itself; if it does, then a fresh glass must be taken, and another trial made. When the process is completed, read off the number of C.C. of ammonium chloride used, allow for the portion of distillate not used, multiply by 0.01 and then by 4: the result is milligrammes of free ammonia per litre, or parts per million; dividing by 10 gives parts 100,000; multiply the latter by 0.7 to bring to grains per gallon.

Example.—From 250 C.C. of water 133 were distilled; 100 C.C. were taken for the experiment; 4.5 C.C. of ammonium chloride solution were required to give the proper color; then $4.5 \times \frac{133}{100} \times 0.01 \times 4 = 0.2394$ milligramme of free ammonia per litre; $0.2394 \div 10 = 0.02394$ per 100,000.

Should the color of the distillate prove too dark, a smaller quantity may be used, and made up to 100 C.C. with distilled water. Wanklyn recommends distilling only 50 C.C., Nesslerizing it, and then adding one-third to the result, on the ground that (as he says) three-fourths of the ammonia come off in the first 50 C.C. He also states that with smaller sized apparatus 100 C.C. of water give satisfactory results.[1] The Society of Public Analysts recommend successive portions being distilled over, and Nesslerized until ammonia ceases to appear. Practically we have found at Netley that the whole of the ammonia comes over in the first 130 C.Cs., or nearly so.

The use of permanent colored solutions, corresponding with known amounts of ammonia, has been recommended, and caramel has been tried at Netley, but the results have not been very satisfactory. A calorimeter may be used if preferred.

When a Liebig's condenser cannot be obtained, a flask may be used instead of a retort, and the distillate conveyed to the receiver by a tube of glass (or block tin) passing through a vessel of cold water, which must be renewed from time to time. The tube may be bent in any convenient way, so as to expose it to the cooling water as much as possible. Every part of the apparatus must be scrupulously clean and well washed with distilled water previous to commencing the experiment. The S.P.A. rec-

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[1] Water Analysis, 5th edition, p. 41.

ommend that the retort tube should be packed into the condensing tube by means of an india-rubber ring ; or it may be done with clean writing-paper, as Wanklyn proposes. In either case the substance used must be quite clean. It is well to wash the retort, flask, and glass tubes with dilute sulphuric acid, and then rinse them out clean with distilled water. In distilling, the retort should be thrust well into the flame, and the distillation carried on rapidly. If the water is very soft the addition of a little pure or recently heated sodium carbonate may be made, but in ordinary circumstances it is not necessary, and is not advisable.

The "free" or "saline ammonia" represents the ammonia combined with carbonic, nitric, or other acids, and also what may be derived from urea, or other easily decomposable substances, if they are present. The limit in good waters is taken at 0.02 milligramme per litre ; in bad waters it often reaches 100 times this and more.[1]

After the distillation of the free ammonia, the residue of the water in the retort is used for determining the *albuminoid ammonia*, to be now described.

(*b*) *Albuminoid Ammonia.*

The object of this process is to get a measure of the nitrogenous organic matter in water, by breaking it up and converting the nitrogen into ammonia by means of potassium permanganate in presence of an alkali ; the ammonia can be distilled off and estimated as above. It is to be understood that this does not deal with all the nitrogenous matter, but the results are sufficiently uniform to be useful. According to Wanklyn and Chapman, the albuminoid ammonia multiplied by 10, gives a fair approximate estimate of the nitrogenous matter in water.

Process.—25 C.C. of the solution of alkaline permanganate[2] are added to the residue in the retort, after the distillation of the free ammonia, and about 110 to 120 C.C. distilled off. It is sometimes convenient to add a little pure distilled water to the residue if the first distillation has been carried rather far. Wanklyn recommends successive quantities of 50 C.C. to be distilled off and tested until no more ammonia comes over. Determine the amount of ammonia, as was done in the case of the free ammonia, and state the results in this case as *albuminoid ammonia.* In this distillation there is sometimes a little difficulty caused by "bumping," especially in the case of bad waters ; to remedy this it has been recommended to use pieces of tobacco-pipe which have been heated to redness immediately before use. It is better, however, to dilute the water if it be a bad one, and not to distil too rapidly.

(*c*) *Nitric Acid.*

Nitric acid may be determined in several ways, but two seem more easily applicable than the others, viz., 1. Schulze's aluminium method (modified by Wanklyn and Chapman) ; and 2. The copper-zinc process. Both methods depend upon the conversion of the nitric acid into ammonia.

1. *Aluminium Process.*—We require solution of caustic soda, perfectly free from nitrates, and aluminium foil.[2] 100 C.C. of the water (50 C.C., S.P.A.) are mixed with an equal bulk of the soda solution, and put into a retort, and a piece of aluminium foil, larger than is capable of dissolving, added. The tube is well corked, and the mixture left for several hours. The liquid is then distilled and Nesslerized ; or, if the quantity of am-

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[1] Wanklyn's Water Analysis, 5th edition, p. 48. [2] See Appendix A, vol. ii.

monia be very large, it may be determined with a standard acid solution. Precautions are suggested for the prevention of the escape of ammonia or the access of ammonia from the air, but with a good cork they are hardly required.

2. *Copper-zinc Process.*—A wet[1] copper-zinc couple is prepared, and well washed with distilled water, and afterward with some of the water to be examined. To use it, put it into a wide-mouthed stoppered bottle, and pour in 100 C.C. of the water to be examined; it is best to fill the bottle up, and to add 1 per 1,000 of sodium chloride, especially if the water be very soft. The stopper is inserted, and the whole put aside for several hours—ten or twelve if the temperature be below 30° C. (86° Fahr.); but the process may be hastened by warming up to 32° to 38° C. (90° to 100° Fahr.). The completion of the process may be ascertained by the absence of *nitrous acid*, when tested for by Griess' test. The water is now to be Nesslerized, which can rarely be done properly except after distillation, as in the former process.

The calculation is made by calculating out the resulting ammonia as nitrogen or as nitric acid—the following being the co-efficients:

1 part of NH_3 = 3.706 of nitric acid, HNO_3 = 3.647 of nitrogen hexoxide, NO_3 = 3.176, nitrogen pentoxide, N_2O_5 = 0.8235 nitrogen, N.

It is necessary to take into account any nitrous acid or ammonia (free or saline) which may be present, and may have been previously determined. Nitrous acid (HNO_2) is to ammonia (NH_3) as 2.765 to 1; or, if nitrogen tetroxide be taken (NO_2), then it is to ammonia (NH_3) as 2.706 to 1.

Example.—100 C.C. of water yielded 0.3371 milligramme of NH_3 after treatment by either of the above processes for the reduction of nitrates; this was equal to 3.371 per litre. But the sample had also yielded 0.052 of free ammonia, and 1.27 of nitrous acid, reckoned as NO_2; the latter, 1.27, divided by 2.706, being equivalent to 0.469 of NH_3; we therefore have

$$3.371-(0.052 + 0.469) = 2.850 \text{ ammonia from nitric acid.}$$

$2.850 \times 3.706 = 10.562\ HNO_3$	$2.850 \times 3.176 = 9.052\ N_2O_5$
$2.850 \times 3.647 = 10.394\ NO_3$	$2.850 \times 0.8235 = 2.347$ N.

Dividing these numbers by 10, we have parts per 100,000, and multiplying this result by 0.7, we have grains per gallon. The statement of the result as *nitrogen* is now becoming very general.

(*d*) *Nitrous Acid.*

For the direct determination of this the plan of Griess is now recommended. A solution of metaphenylenediamine is prepared, and also a dilute sulphuric acid, consisting of one volume of strong acid to two of water. One C.C. of each solution is added to 100 C.C. of the water to be examined, which is put in a Nessler glass: a red color is produced. Another glass is placed alongside, and into it are put as much of a standard solution of potassium nitrite as may be necessary, making up the bulk to 100 C.C. with distilled water; then add 1 C.C. each of the sulphuric acid and the metaphenylenediamine. The remainder of the process is carried

[1] In Frankland's Water Analysis, p. 100, the directions given are for a *dry* couple, which appears to be an error. See M. W. Williams, Analyst, vol. vi., p. 36. For preparation, see Appendix A, vol. ii.

on much in the same way as ordinary Nesslerizing for ammonia. Care must be taken that the water originally taken is not too strong, so if the red color be too deep, smaller portions diluted up to 100 C.C. must be taken, until the faintest tint distinctly recognizable is obtained. The standard potassium nitrite[1] should be of the strength 1 C.C. = 0.01 milligramme of NO_2, or nitrogen tetroxide. The number of C.C. used gives the milligrammes of NO_2 present in the sample of water.

Example.—A sample of water containing a good deal of nitrous acid was taken, and 25 C.C., made up to 100 C.C. with pure distilled water, were put in a Nessler glass. 1 C.C. of the sulphuric acid and 1 C.C. of the solution of metaphenylenediamine added: a distinct red color was obtained. Into another Nessler glass 7.5 C.Cs. of the standard potassium nitrite were put, made up to 100 C.C. with distilled water, and the same shade of tint obtained with the solutions as above.

$$\begin{aligned} 7.5 \times .01 &= \overset{\text{Mgm.}}{0.075}\ NO_2 \text{ in 25 C.Cs.} \\ 0.075 \times 4 &= 0.300\ NO_2 \text{ in 100 C.Cs.} \end{aligned}$$

This equals 0.3 in 100,000 or 0.21 in 1 gallon; multiplying any of these results by 0.304, gives the amount of nitrogen (N).

The above is now accepted as the most accurate method of determining nitrites,[2] but some care is required—for both the water and the coloring solution must be either colorless or be decolorized. It may not be always possible to get the reagents, and then it is best to fall back upon the determination of nitrous acid by the permanganate process to be presently described.

It may be well to mention here that the method of stating the results varies, as in the case of nitric acid, some reckoning as HNO_2, some as N_2O_3, and others as NO_2. The last is the best, as it corresponds to Cl. In the same way NO_3 is to be preferred for the nitric acid, SO_4 for the sulphuric acid, and PO_4 for the phosphoric acid.

(B) *Determination of Oxidizable Matter in Water.*

The oxidizable matter in water consists of oxidizable organic matter, nitrites, ferrous salts, and hydrogen sulphide. The last can be easily recognized by the smell, and got rid of by gently warming the water. Ferrous salts are rare, but, if present, they impart a distinct chalybeate taste to the water if their amount reaches the fifth of a grain of iron per gallon (about 0.3 part per 100,000). Generally their presence may be disregarded. There remain, therefore, the oxidizable organic matter, and nitrous acid as nitrites. For determining these the potassium permanganate is very convenient.

(e_1) *Total Oxidizable Matter in terms of Oxygen required for its Oxidation.*—A solution of potassium permanganate is required, which in presence of an acid is capable of yielding 0.1 milligramme of oxygen for each C.C.

Process.—Take a convenient quantity of the water to be examined, say 250 C.C.; add 3 C.C. of sulphuric acid; drop in the permanganate solution from a burette until a pink color is established; warm the water up to 140° Fahr. (60° C.), dropping in more permanganate if the color disappears; when the temperature reaches 140° Fahr. remove the lamp; con-

[1] For the preparation of the solutions, see Appendix A, vol. ii.

[2] See Frankland, Water Analysis, p. 40; also M. W. Williams, in Analyst, vol. vi., p. 36.

tinue to drop in permanganate until the color is permanent for about ten minutes. Then read off the number of C.C. used, multiply by 0.1 to get the milligrammes of oxygen, and by 4 to get the amount per litre.

Example.—250 C.C. of water, with 3 C.C. of sulphuric acid, required 3.5 C.C. of permanganate to give a permanent color; $3.5 \times 0.1 \times 4 = 1.4$ milligramme of oxygen per litre required for *total* oxidizable matter, $1.4 \times 0.1 = 0.14$ per 100,000.[1]

It must be remembered that this includes both organic matter and nitrous acid. We must now differentiate these.

(e_2) *Organic Oxidizable Matter in terms of Oxygen required for its Oxidation.*—Take 250 C.C. of water to be examined; add 3 C.C. of sulphuric acid as above; boil the water briskly for twenty minutes; allow it to cool down to 140° Fahr. (60° C.); then add the permanganate until a pink color is established for ten minutes. Calculate out the oxygen as above, stating the result as milligrammes per litre required for oxidizable organic matter, or, shortly, as *organic oxygen.*

The rationale of this process is the driving off of the nitrous acid by boiling with sulphuric acid.

(e_3) *Nitrous Acid.*—This can now be determined easily by calculating from the difference between the two preceding processes. Each milligramme of oxygen represents 2.875 milligrammes of nitrous acid; we must therefore multiply the difference by this factor, and the result is nitrous acid in milligrammes per litre.

Example.—A sample of water yielded, by process (e_1), 0.14 part of oxygen per 100,000; by process (e_2), 0.075. Then we have $0.140 - 0.075 = 0.065$ = centigramme or 0.65 milligramme of oxygen required for nitrous acid, $0.65 \times 2.875 = 1.87$ milligramme per litre of nitrogen tetroxide (NO_2); $1.87 \times 0.1 = 0.187$ per 100,000.

Hassall[2] has suggested an improvement on the above process (de Chaumont's), namely, instead of boiling away the nitrous acid, to distil it over and determine it directly in the distillate. Fresenius proposes a somewhat similar plan, only using acetic acid for the distillation, and then sulphuric acid for the subsequent titration. Of course, if distillation is resorted to, the NO_2 can be determined by Griess' method.

One or two precautions are necessary in the permanganate processes. In process (e_1) permanganate must be added to the water from the very commencement, in order not to lose nitrous acid, which may be driven off as the water is being heated. The faintest tinge of color that can be distinctly seen ought to be accepted, provided it remain for ten minutes. Care must be taken to add the sulphuric acid in every case at the beginning; if this is not done a brown color is struck which spoils the experiment. Sometimes this color appears, even after acid is added, and is then probably due to excess of organic matter; dilution with distilled water sometimes remedies this. The permanganate solution always acts upon the india-rubber tube of the common burette, therefore it is always well to use a burette with a glass stop-cock, or to run off the portion which has been in contact with the india-rubber, before beginning the experiment.

The S.P.A. instructions recommend another method of operation (suggested by Tidy) including two determinations, viz., one in which the oxygen absorbed within fifteen minutes is calculated, and another within four

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[1] If special accuracy is required, a correction for color may be made, by deducting 0.06 from the result stated as milligrammes of oxygen per litre.

[2] Adulterations Detected, 1876, p. 84.

hours. The processes are carried on at a temperature of 80° Fahr. (26.7° C.). Two bottles, stoppered and of about 12 oz. (340 C.C.) capacity, are used, into each (after being thoroughly cleaned, rinsed with sulphuric acid and then with the water to be examined) 250 C.C. of the water are to be put, and warmed in a bath to 80° Fahr. (26.7° C.). Then add 10. C.C. of dilute sulphuric acid (1 vol. to 3 vols. of water) and 10 C.C. of the standard potassium permanganate solution. Fifteen minutes after the addition of the potassium permanganate, one of the bottles must be removed from the bath, and two or three drops of the potassium iodide solution added, to remove the pink color. After thorough mixture, run from a burette the standard solution of sodium hyposulphite, until the yellow color is nearly destroyed, then add a few drops of starch water, and continue the addition of the hyposulphite until the blue color is discharged. If the titration has been properly conducted, the addition of one drop of potassium permanganate solution will restore the blue color. At the end of four hours remove the other bottle, and titrate as above described. Should the pink color of the water in the bottle diminish rapidly during the four hours, further measured quantities of the standard solution of potassium permanganate must be added from time to time, so as to keep it markedly pink.

The hyposulphite solution must be *standardized* by making a blank experiment with distilled water, and this must be repeated from time to time as it does not keep well. Let A be the quantity of hyposulphite required in the blank experiment, and let B be the amount required for 250 C.C. of the water examined,—then :

$$(A - B) \times 0.01 = \text{oxygen absorbed per 100,000 parts:}$$

this multiplied by 10 gives the milligrammes per litre.

It is of course to be understood that the nitrous acid, if present, must be allowed for, and other oxidizable substances eliminated before the oxygen for organic matter is definitively recorded.

The permanganate process is the only one that is practicable for medical officers, that gives us any measure of the oxidizable organic matter in water, and is, in the present state of our knowledge, indispensable, imperfect though its indication may be. It is certainly an aid to our judgment of the condition of a drinking water, being to Frankland's carbon process something the same as the albuminoid ammonia method is to his nitrogen one. Frankland has fully acknowledged this relation in his latest work,[1] and has proposed a series of factors by which to multiply the oxygen absorbed, so as to express the result in terms of organic carbon. These factors are based on the observed relations between the two processes in a very large number of experiments, and are formed by dividing the average carbon by the average oxygen. The factors differ for different kinds of water in the following proportions:

River water,	$\frac{C}{O}$	=	2.38
Deep well water,	"	=	5.80
Shallow well water,	"	=	2.28
Upland surface water,	"	=	1.80

so that 1 milligramme of oxygen absorbed indicates a probable amount of only 1.8 of organic carbon in an upland surface water, but as much as 5.8 in a deep well water.

[1] Water Analysis, 1880, p. 55.

No process gives us thoroughly trustworthy information, but for the army or navy medical officer, or any one not provided with a well-appointed laboratory, the permanganate process, combined with the albuminoid ammonia process, gives as much information as is likely to be got at present, and sufficient for hygienic purposes. It must be remembered that the permanganate does not act upon fatty substances, starch, urea, hippuric acid, creatin, sugar, or gelatine.

Action of Permanganate in presence of an Alkali.

In order to avoid some of the fallacies and inconveniences of the test with acid, F. Schultze[1] tried the following plan, which was slightly modified by Lex. Five or more vessels, each containing 60 C.C. of the water to be examined, are taken, and to each 2 C.C. of thin milk of lime are added, and then 1, 2, 3, 4, 5 C.C., etc., of the permanganate solution (viz., .395 gramme per litre) are added, and left for three hours. At the end of that time some of the samples will be decolorized, others still colored; if No. 1 and No. 2 are colorless, and No. 3 is colored, then the amount of permanganate destroyed is between 2 and 3 C.C. As in the cold each equivalent of permanganate only gives off 3 (not 5 atoms) of oxygen, each C.C. corresponds not to .1, but to .06 milligramme of oxygen.[2] It is for this reason that 60 C.C. of water are taken instead of 100, for it is evident that if 1 C.C. of the permanganate solution gives only .06 milligramme to 60 C.C., it is the same as .1 to 100 C.C. of the water. The calculation of the results is thus easy; if, for example, Nos. 1 and 2 are decolorized, while No. 3 is colored, the amount of oxygen required is between .2 and .3 milligramme for 100 C.C., or 2 and 3 per litre. If 60 C.C. of a water take less than 3 C.C. of the permanganate solution to give it a color permanent for two hours, it is a good water (according to Lex) so far as this test is concerned; if 3 and 4 C.C. are required it is a medium water, and if the 5 C.C. do not give a color the water is bad.

5. PHOSPHORIC ACID IN PHOSPHATES.

The incinerated total residue of the solids is to be treated with a few drops of nitric acid, and the silica rendered insoluble by evaporation to dryness. The residue is then taken up with a few drops of dilute nitric acid, some water is added, and the solution is filtered through a filter previously washed with dilute nitric acid. The filtrate, which should measure 3 C.Cs., is mixed with 3 C.C. of molybdate solution, gently warmed, and set aside for fifteen minutes at a temperature of 80° Fahr. The result is reported as "traces," "heavy traces," or "very heavy traces," when a color, turbidity, or definite precipitate are respectively produced, after standing fifteen minutes. The precipitate may also be collected and weighed, if thought desirable. For this purpose it ought to be washed with the least quantity of distilled water, and then dissolved to neutrality in dilute ammonia. The solution thus obtained is evaporated with repeated additions of small quantities of water, and the resulting residue is weighed. The weight, divided by 28.6, gives the amount of phosphoric

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[1] Roth and Lex, op. cit., p. 91.

[2] With sulphuric acid the following is the reaction:

$$2\,(KMnO_4) + 3(H_2SO_4) = K_2SO_4 + 2(MnSO_4) + 3(H_2O) + O_5$$

without acid the reaction is:

$$2(KMnO_5) + H_2O = 2(MnO_2) + 2(KHO) + O_3.$$

anhydride, P_2O_5 (Hehner). To express it in terms of PO_4, divide by 21.4, or multiply by 0.0467.

6. The determination of *sulphuric acid* has been already referred to (page 90, note).

Determination of the Earthy and Alkaline Carbonates by Mohr's Process.

This is a very elegant process, and may be useful. The solutions required are: standard solution of sulphuric acid,[1] 1 C.C. of which saturates 5 mgms. of calcium carbonate; and a coloring solution, such as cochineal or phenolphthaleine.

Process.—Take 70 C.C. of the water to examine, and add a drop or two of cochineal solution, which gives a carmine red color. Then run in the standard acid solution till the color becomes yellow or brown-yellow. Read off the number of C.C. used, and multiply by 5. The result is grains of earthy and alkaline carbonates per gallon, stated at calcium carbonate. Divide the result by 0.7 to get parts per 100,000.

Example.—70 C.C. of a sample of water, reddened with cochineal, required 3.9 of standard solution to make it yellow:—then $3.9 \times 5 = 19.5 =$ grains per gallon of earthy and alkaline carbonates as calcium carbonate, and $19.5 \div 0.7 = 27.857$ parts per 100,000. If the water be not alkaline to test paper, the result will represent calcium carbonate only. Should the latter be already known (through the hardness), the difference, if any, will represent sodium carbonate, and may be calculated out as such, 1 C.C. $= 5.3$ mgms. of sodium carbonate.

Iron, Silica, Lead, Copper, Arsenic, Zinc.

Iron is seldom required to be determined quantitatively, but it may be done by a colorimetric test (as suggested by Wanklyn). Either the water may be tested directly, or, what is better, the incinerated residue of the solids may be treated with pure hydrochloric acid, and made up to 100 C. C. with distilled water. A cubic centimeter of solution of ferrocyanide of potassium is added, which will strike a blue color. A comparative experiment with a standard solution of iron may be made.[2] This is a better process than the permanganate method, which with small quantities of iron gives very uncertain results.

Silica may be determined from the incinerated residue by treating it with strong nitric or hydrochloric acid, evaporating to dryness, and again treating with acid; distilled water (about 50 C.C.) is then added, and a little heat applied till everything soluble is dissolved; the residue is silica, which may be collected on a small filter, ignited and weighed. A number of Indian waters contain considerable quantities of silica, either combined or in the suspended matter.[3]

Lead, Copper, Arsenic, Zinc.—The mere presence of these metals in appreciable quantity is enough to condemn a water, therefore it will seldom be necessary to determine their amount quantitatively.

Inferences from the Quantitative Tests.

The conclusions to be drawn from the qualitative tests hold good for the quantitative, only greater precision is given. It must, however, be under-

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[1] See Appendix A, Vol. ii. [2] See under *Alum in bread.*

[3] Dr. Nicholson, A.M.D., has noticed that the water at Kamptee, both from the river and from wells, contains from 2 to 6 grains per gallon of silica derived from micaceous gravel; it is combined with magnesia, and it renders the soap test inapplicable.

stood that such conclusions are still only approximative, and they are only of a certain value when all the circumstances of the case are taken into consideration. Some chemists have gone so far as to say that they would rather know nothing about the sample, and merely wish it marked with some distinctive mark, such as A or B, or 1 or 2 ; their confidence being so great in the indications of their analyses, that they feel convinced they can give a perfectly trustworthy opinion on the wholesomeness or otherwise from these alone. There is no doubt that a practised chemist may make a fairly good *guess* under such circumstances, but as a rule an opinion so formed is worth very little. It is, of course, desirable that an analyst should come to his inquiry perfectly unbiassed ; but before adopting a conclusion as regards a water the medical officer will always do well to obtain every item of information about it that is possible to get,—otherwise he is sure to fall sooner or later into error. Thus, constituents may be present in a deep well-water and have no particular significance, whilst in a shallow well-water they would be sufficient to condemn it. At present we have little or no means of positively distinguishing vegetable from animal organic matter ; yet it is obvious that an amount of the former would be admissible which could not be allowed of the latter.

Mr. Wigner has proposed a scale of valuation, in which a certain numerical value is attached to each constituent.[1] The scale is an ingenious one, but it would hardly be advisable to adopt it definitively as yet, and the Society of Public Analysts have declined to do so for the present.

The inadvisability of drawing hard and fast lines on the subject is being now more generally recognized ; and the remark of Mr. Charles Ekin[2] is very apposite, for he says it is as if *six* typhoid germs were harmless and *nine* were hurtful. It may be true that the larger the dose of poison the more certain the effect, but we know too little at present to allow us to say where the line is to be drawn. At the same time, some approximation to classification may be made. The Reports on Hygiene in the *A. M. D. Annual Reports*, vols. xviii. to xxi., may be referred to for tables of water analyses, with approximate classifications.

Subjoined, in pp. 103–106, are tables of typical waters divided into four classes,—1. Pure and wholesome ; 2. Usable ; 3. Suspicious ; and 4. Impure. These are merely suggested as general guides, some latitude being necessary, according to circumstances.

1. *Chlorine in Chlorides.*—The purest waters contain small quantities of chlorides, generally less than one grain of chlorine per gallon (1.4 per 100,000). Rain-water generally contains 0.22 to 0.5 per 100,000 (0.15 to .35 per gallon). An increase in ordinary drinking-water may be due to sea-water, salt-bearing strata, or sewage, or other impurities. In the two former cases it is comparatively innocent, but in the last it may be an indication of dangerous contamination, in which case it is usually connected with an increase in the ammonias, the oxidizable matter and the nitrogen acids. Sewage contamination can never take place without some increase in the chlorides, unless it be through gaseous emanations. Some deep wells contain large quantities of chlorides, but the other details of the analysis will show that this is not due to any recent contamination. Generally speaking, however, an excess of chlorine is a reason for suspicion, until a satisfactory explanation of its presence is obtained.[3]

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[1] See Analyst, vol. vi., p. 122.

[2] Potable Water, by Charles Ekin, F.C.S. J. & A. Churchill.

[3] Good deep well-water may contain 10 grains of chlorine per gallon : sewage effluent (as at Aldershot) only 2.8.

2. *Solids, Total and Volatile.*—The amount of solids varies very greatly with the source of the water. Pure upland surface waters contain very little, sometimes not more than 2 or 3 grains in a gallon. The Loch Katrine water, supplied to Glasgow, yields only 1.68 per gallon (2.4 per 100,000); Thirlmere Lake, proposed as the supply for Manchester, about the same; and Vyrnwy, proposed as the supply for Liverpool, 2.38 per gallon or 3.4 per 100,000.

On the other hand, waters from pure sources other than upland surface show much more than this. On the whole, we may lay it down that the purest upland surface waters seldom contain more than about 5 grains per gallon (or about 7 parts per 100,000), but that considerable latitude may be admitted in waters from deep wells, chalk strata, and the like.

Of the solids not more than about 1 grain per gallon (1.4 per 100,000) ought to be volatile, or capable of being driven off by a red heat. The solids should blacken very slightly on ignition. A little deviation from this rule is admissible in water from peat land.

3. *Ammonia, Free and Albuminoid.*—Pure waters yield from *nil* to 0.002 per 100,000 of free ammonia, and from *nil* to 0.005 per 100,000 of albuminoid ammonia. Usable water may contain up to 0.005 per 100,000 of free, and 0.01 per 100,000 of albuminoid ammonia. These numbers, however, require qualification, for they may be exceeded in cases where water is thoroughly good for dietetic purposes. Rain water often contains a large amount of free ammonia, probably derived from soot, and it appears to be harmless.

Deep wells often show a large amount of free ammonia and chlorides without necessarily indicating pollution; but the same amounts in a shallow well would point to probable sewage pollution, or at least to the presence of urine.

The presence of a considerable amount of albuminoid ammonia, with little free ammonia and chlorides, is generally indicative of vegetable organic matter, often peaty. This is the character of the greater part of the water supply of Ireland.

The real significance of the albuminoid ammonia, has been much discussed, but the results obtained are sufficiently uniform to give us a convenient measure of purity, provided we are careful not to draw the line too close. All the nitrogen of the organic matter is certainly not obtained by this method, but this is immaterial so long as the proportion is fairly maintained. The results correspond to a certain extent with the *organic nitrogen* of Frankland, and the process is much more feasible for medical officers generally.

4. *Nitric and Nitrous Acids in Nitrates and Nitrites.*—The significance of these is very important. Nitric acid is the ultimate stage of oxidation of nitrogenous organic matter, and when present in water it is almost always the result of previous pollution, either of the water itself or of the strata through which it flows. It gives us no information, however, as to the exact time when the pollution took place. In some samples from deep wells it is evident that the pollution must have been very ancient. It has been distinctly shown by Schloesing and Muntz [1] and by R. Warington [2] that nitrification is a fermentative process excited and carried on through the agency of a minute organism, just as ordinary fermentation is carried on through the medium of *torula*. Nitrous acid indicates the presence of

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[1] Comptes Rendus, lxxxiv., 301; lxxxv., 1018; lxxxvi., 892; lxxxix., 891, 1074.
[2] Chem. Soc. Journ., 1878, xxviii., 44; 1879, 429. Chem. News, xliv., 217.

organic matter undergoing change: it is either a stage in the direct oxidation of such matter, progressive or arrested, or a retrogression from nitric acid in consequence of the latter having yielded up a part of its oxygen. In this way nitrous acid might retrograde still further and become converted again into ammonia, or be dissipated as nitrogen. Nitrous acid is a much more important substance than nitric, as indicating present danger, and a very small amount of it is sufficient to remove a water into the suspicious class. It is rare to find any of the higher forms of life in a water rich in nitrites, although *bacteria* may be found. Pure water ought to be quite free from nitrites, and ought to show only traces at most of nitrates,—the limit being about 0.032 per 100,000 of nitric acid,—representing of combined nitrogen 0.014 per 100,000. The total combined nitrogen (including that in the free ammonia) would be 0.016 per 100,000; whilst the total nitrogen (including that in the albuminoid ammonia) would be 0.023 per 100,000. The *presence* of nitrites is suspicious: the marked presence of nitrates ought to be a ground for careful inquiry. In some soils, especially sands and gravels, and in ferruginous soils the process of nitrification goes on extremely rapidly, and the existence of impurity may escape notice if the examination for nitric acid be omitted.

5. *Oxygen absorbed.*—This ought not to exceed about 0.0250 per 100,000 for organic matter alone,—that is, after deducting any that may be absorbed by nitrous acid if present. This latter, however, should not be present in a water of the first class. The experiment to be done with permanganate and acid at a temperature of 140° Fahr. (60° C.).

Frankland and Wigner allow four times the above amount for upland surface waters, and double the above amount for other waters,—the experiment being performed for four hours at a temperature of 80° Fahr. (27° C.).

In water with little chlorine and little or no free ammonia, a higher amount than the above may be present without danger, as in all probability it will be due to vegetable matter.

6. *Hardness.*—The fixed hardness should not exceed 2° of Clark's scale, or 3° of the metrical scale. The total hardness may vary more, but if possible should not exceed 5° or 6° (Clark), or 7° to 8.5° (metrical).

7. *Phosphates.*—The presence of these in any marked quantity will generally corroborate inferences as regards sewage contamination drawn from the other indications.

Sulphates.—An excess of sulphates will in many cases also indicate contamination, though they may, like chlorine, come from innocuous sources.

8. *Metals.*—Pure water should contain no *heavy metal*, although a trace of iron may be found sometimes. In some cases iron seems beneficial, as it helps to oxidize the organic matter. The presence of any other *heavy metal* ought to condemn the water.

9. The presencee of *hydrogen sulphide* or *alkaline sulphides* ought to condemn the water.

It is always advisable to get information if possible as to the *usual* composition of a water to be examined, as even slight variations may suggest a clue to the nature or cause of an impurity. The microscopic examination of the sediment ought always to be performed where possible, as it often affords important information when the chemical investigation fails. Thus, the presence of such objects as muscular fibre, wheaten starch cells, mucous epithelium, disintegrating masses of paper, etc., are sufficient alone to condemn water (especially if it be from a shallow well), even when the chemical constituents are within limits, as they are undoubted evidences

of animal contamination, almost certainly sewage. In such cases the nitric acid is nearly always large in amount.

The following is the form of Report at present used at Netley:

Report on a Sample of Drinking Water.

From	Drawn	18
Source	Received	18
	Examined	18

Physical Characters.

Color (*through* 18 *ins.*)	Lustre....................
Turbidity	Taste.....................
Sediment	Smell ....

Chemical Analysis.

Qualitative (*water unconcentrated*).

Lime	Ammonia ....
Magnesia...................	Nitric acid................
Chlorine	Nitrous acid ....
Sulphuric acid..............	Oxidizable matter..........
Phosphoric acid.............	Iron or Lead ....

Hardness.

Fixed....................		Degrees of Clark's Scale.	=		parts per 100,000.
Temporary or Removable ..					
Total..........					

Quantitative.	Grains per gallon.	Parts per 100,000.
Volatile matter (by incineration and after re-carbonating)....		
Oxygen required for oxidizable organic matter.. (Parts per 100,000.)		
Ammonia free .... (Parts per 100,000.)		
Ammonia albuminoid.... (Parts per 100,000.)		
Nitric acid (NO_3)........ (Parts per 100,000.)		
Nitrous acid (NO_2)....... (Parts per 100,000.)		
Total nitrogen included in nitrates and nitrites (Parts per 100,000.)		
Chlorine		
Calcium carbonate		
Fixed hard salts		
Sulphuric acid (SO_4)		
Alkaline carbonates		
Sodium or other metal (combined with Cl or SO_4) not included in fixed hard salts		
Silica, alumina, iron, etc................................		
Total solids (by evaporation)........		

N.B.—These constituents, with the oxidizable organic matter, indicated by the oxygen required, are included in the *Volatile Matter.*

Microscopic Characters.

Remarks.

Professor of Military Hygiene.

Laboratory, Army Medical School,
Royal Victoria Hospital, Netley,

The following tables give an approximate view of the composition of drinking waters of the four classes:

1. *Pure and Wholesome Water.*

Character or Constituents.			Remarks.
Physical characters: Colorless, or bluish tint; transparent, sparkling, and well aërated; no sediment visible to naked eye; no smell; taste palatable.			Turbidity, due to very fine mineral matter, is sometimes associated with pure waters; thus, minutely divided calcium sulphate will not subside in distilled water.
Chemical Constituents.	**Grains per gallon, 1 in 70,000.**	**Centigrammes per litre, 1 in 100,000.**	
1. Chlorine in chlorides.....*under*	1.0000	1.4000	This may be exceeded if from a purely mineral source.
2. Solids in solution: total..*under*	5.0000	7.1428	The solids may be exceeded in chalk waters, where they are mostly calcium carbonate.
Solids in solution: volatile, *under*	1.0000	1.4000	
N.B.—The solids on incineration should scarcely blacken.			
3. Ammonia, free or saline..*under*	0.0014	0.0020	
Ammonia, albuminoid...*under*	0.0035	0.0050	
4. Nitric acid (NO_3), in nitrates......*under*	0.0226	0.0323	
Nitrous acid (NO_2), in nitrites..........	nil.	nil.	
Nitrogen in nitrates.....*under*	0.0100	0.0140	
Total combined nitrogen, including that in the free ammonia................*under*	0.0112	0.0160	
Total nitrogen, including that in the albuminoid ammonia................*under*	0.0160	0.0230	
5. Oxygen absorbed by organic matter within half an hour, by permanganate and acid at 140° F. (60° C.).......*under*	0.0175	0.0250	The oxygen absorbed may be *doubled* in peat or upland surface waters.
Do. in fifteen minutes, at 80° F. (27° C.)..............*under*	0.0100	0.0125	
Do. in four hours, at 80° F. (27° C.)..............*under*	0.0350	0.0500	
6. Hardness, total.........*under*	6.0°	8.5°	
Hardness, fixed.........*under*	2.0°	3.0°	
7. Phosphoric acid in phosphates....................	traces.		
Sulphuric acid in sulphates....	traces.		
8. Heavy metals................	nil.		
9. Hydrogen sulphide, alkaline sulphides..................	nil.		
Microscopic characters: Mineral matter; vegetable forms with endochrome; large animal forms; no organic debris.			

A water such as the above may generally be used with confidence, in the absence of any history of possible pollution, or of any recent and appreciable change in the amount of the organic constituents.

2. *Usable Water.*

Character or Constituents.			Remarks.
Physical characters: Colorless, or slightly greenish tint; transparent, sparkling, and well-aërated; no suspended matter, or else easily separated by coarse filtration or subsidence; no smell; taste palatable.			In some usable waters, such as peat waters, the color may be yellow or even brownish. In some also the taste may be flat or only moderately palatable.
Chemical Constituents.	**Grains per gallon, 1 in 70,000.**	**Centigrammes per litre. 1 in 100,000.**	
1. Chlorine in chlorides.....*under*	3.0000	4.2857	This may be much larger in waters near the sea, deep well waters, or waters from saline strata.
2. Solids in solution: total..*under*	30.0000	42.8571	
Solids in solution: volatile, *under*	3.0000	4.2857	The solids may blacken, but no nitrous fumes should be given off.
3. Ammonia, free or saline, *under*	0.0035	0.0050	This may be greater in deep well waters.
Ammonia, albuminoid ...*under*	0.0070	0.0100	This may be larger in upland surface waters, peat waters, etc., when the source is chiefly vegetable.
4. Nitric acid (NO_3), in nitrates.. .. ..*under*	0.3500	0.5000	The amount of nitrates varies greatly, so that an average is of doubtful value.
Nitrous acid (NO_2), in nitrites	nil.	nil.	
Nitrogen in nitrates .....*under*	0.0790	0.1129	
Total combined nitrogen, including that in free ammonia ....*under*	0.0819	0.1170	
Total nitrogen, including that in albuminoid ammonia ..*under*	0.0876	0.1252	
5. Oxygen absorbed by organic matter within half an hour, by permanganate and acid, at 140° F. (60° C.).....*under*	0.0700	0.1000	The oxygen absorbed may be greater (about *double*) in upland surface waters, peat waters, etc.
Do. in fifteen minutes, at 80° F. (27° C.) ....*under*	0.0210	0.0300	
Do. in four hours, at 80° F. (27° C.) ....*under*	0.1050	0.1500	
6. Hardness, total ....*under*	12.0°	17.3°	
Hardness, fixed ....*under*	4.0°	5.7°	
7. Phosphoric acid in phosphates..	traces.	traces.	
Sulphuric acid in sulphates.............. *under*	2.000	3.0000	In some waters the amount may be larger.
8. Heavy metals—Iron	traces.	traces.	
9. Hydrogen sulphide, alkaline sulphides..................	nil.	nil.	
Microscopic characters: same as No. 1.			

A water such as the above will in most cases be usable, but it will be improved by filtration through a good medium.

3. *Suspicious Water.*

Character or Constituents.			Remarks.
Physical characters: Yellow or strong green color; turbid; suspended matter considerable; no smell, but any marked taste.			Where the impurity is mostly vegetable, the color may be very marked in usable water.
Chemical Constituents.	Grains per gallon. 1 in 70,000.	Centigrammes per litre. 1 in 100,000.	
1. Chlorine in chlorides..........	3 to 5	4 to 7	In some cases the chlorine may be greater.
2. Solids in solution: total	30 to 50	43 to 71	
Solids in solution: volatile	3 to 5	4 to 7	
3. Ammonia, free or saline	0.0035 to 0.0070	0.0050 to 0.0100	
Ammonia, albuminoid	0.0070 to 0.0087	0.0100 to 0.0125	
4. Nitric acid (NO_3), in nitrates ..	0.35 to 0.70	0.5 to 1.0	
Nitrous acid (NO_2), in nitrites..	0.0350	0 0500	
Nitrogen in nitrates and nitrites....................	0.0870 to 0.1661	0.1243 to 0.2373	
Total combined nitrogen, including that in free ammonia....................	0.0871 to 0.1718	0.1247 to 0.2455	
Total nitrogen, including that in albuminoid ammonia.....	0.0879 to 0.1726	0.1255 to 0.2465	
5. Oxygen absorbed by organic matter within half an hour, by permanganate and acid, at 140° F. (80° C.)	0.0700 to 0.1050	0.1000 to 0.1500	
Do. in fifteen minutes, at 80° F. (27° C.)	0.0350 to 0.0700	0.0500 to 0.1000	
Do. in four hours, at 80° F. (27° C.)	0.1500 to 0.2800	0.2000 to 0.4000	
6. Hardness, total ....*above*	12.0°	17.0°	
Hardness, fixed ....*above*	4.0°	5.7°	
7. Phosphoric acid in phosphates	heavy	traces.	
Sulphuric acid in sulphates .... *above*	2.000	3.000	This may sometimes be larger.
8. Heavy metals—iron	traces.	traces.	
9. Hydrogen sulphide, alkaline sulphides	nil.	nil.	
Microscopic characters: Vegetable and animal forms more or less pale and colorless; organic debris; fibres of clothing, or other evidence of house refuse.			

A water such as the above ought to excite suspicion: its use ought to be suspended until inquiries about it can be made; if it must be used, it ought to be boiled and filtered.

4. *Impure Water.*

Character or Constituents.			Remarks.
Physical characters: Color, yellow or brown; turbid, and not easily purified by coarse filtration; large amount of suspended matter; any marked smell or taste.			Dark colored waters may be usable when the impurity is vegetable.
Chemical Constituents.	**Grains per gallon. 1 in 70,000.**	**Centigrammes per litre. 1 in 100,000.**	
1. Chlorine in chlorides.....*above*	5.0000	7.1428	Chlorides *per se* are not hurtful, unless they are magnesian or in some quantity.
2. Solids in solution: total..*above*	50.0000	71.4285	
Solids in solution: volatile, *above*	5.0000	7.1428	
3. Ammonia, free or saline..*above*	0.0070	0.0100	
Ammonia, albuminoid....*above*	0.0087	0.0125	
4. Nitric acid (NO_3), in nitrates.....*above*	0.7000	1.0000	Some waters, which are organically pure, contain a great excess of solids.
Nitrous acid (NO_2), in nitrites ......*above*	0.0350	0.0500	
Nitrogen in nitrates and nitrites.................*above*	0.1690	0.2415	
Total combined nitrogen, including that in free ammonia................*above*	0.1748	0.2497	
Total nitrogen, including that in albuminoid ammonia..................*above*	0.1821	0.2601	
5. Oxygen absorbed by organic matter within half an hour, by permanganate and acid, at 140° F. (60° C.).....*above*	0.1050	0.1500	In the absence of free ammonia, or much chlorine, this may be due to vegetable matter.
Do. in fifteen minutes, at 80° F. (27° C.)..............*above*	0.0700	0.1000	
Do. in four hours, at 80° F. (27° C.)...............*above*	0.2800	0.4000	
6. Hardness, total..........*above*	20.0°	28.5°	
Hardness, fixed ....*above*	6.0°	8.7°	
7. Phosphoric acid in phosphates	Very heavy traces.		
Sulphuric acid in sulphates ....*above*	3.000	4.2857	
8. Heavy metals.................	Any except iron.		
9. Hydrogen sulphide	present.		
Alkaline sulphides............			
Microscopic characters: *Bacteria* of any kind; *fungi;* numerous vegetable and animal forms of low types; epithelia or other animal structures; evidences of sewage; ova of parasites, etc.			

A water such as the above ought to be absolutely condemned. Should stress of circumstances compel its use, it ought to be well boiled and filtered; or, better still, distilled.

SECTION VI.

Sub-Section I.—Search after Water.

Occasionally a medical officer may be in a position in which he has to search for water. Few precise rules can be laid down.

On a plain, the depth at which water will be found will depend on the permeability of the soil, and the depth at which hard rock or clay will hold up water. The plain should be well surveyed; and if any part seems below the general level, a well should be sunk, or trials made with Norton's tube-wells. The part most covered with herbage is likely to have the water nearest the surface. On a dry sandy plain, morning mists or swarms of insects are said sometimes to mark water below. Near the sea, water is generally found; even close to the sea it may be fresh, if a large body of fresh water flowing from higher ground holds back the salt water. But usually wells sunk near the sea are brackish; and it is necessary to sink several, passing farther and farther inland, till the point is reached where the fresh water has the predominance.

Among the hills the search for water is easier. The hills store up water, which runs off into plains at their feet. Wells should be sunk at the foot of hills, not on a spur, but, if possible, at the lowest point; and if there are any indications of a water-course, as near there as possible. In the valleys among hills, the junction of two long valleys will, especially if there is any narrowing, generally give water. The outlet of the longest valleys should be chosen, and if there is any trace of the junction of two water-courses, the well should be sunk at their union. In a long valley with a contraction, water should be sought for on the mountain side of the contraction. In digging at the side of a valley, the side with the highest hill should be chosen.

Before commencing to dig, the country should be as carefully looked over as time and opportunity permit, and the dip of the strata made out, if possible. A little search will sometimes show which is the direction of fall from high grounds or a water-shed.

If moist ground only is reached, the insertion of a tube, pierced with holes, deep in the moist ground, will sometimes cause a good deal of water to be collected. Norton's American tube-well gave satisfaction in Abyssinia, although it did not succeed so well in Ashantee. A common pump will raise the water in it if the depth be not more than 24 or 26 feet; if deeper, a special force-pump has to be used.

Sub-Section II.—Special Considerations on the Supply of Water to Soldiers.

In barracks and hospitals, and in all the usual stations, all that has to be done is to make periodical examinations of the quantity and quality of the water, to inspect the cisterns, etc., and to consider frequently if in any way wells or cisterns can have been contaminated. As far as possible, a record should be kept at each station of the normal composition of the water.

In transport ships, the water and the casks or tanks should always be examined before going to sea. Should it show signs of putridity, distillation of sea-water, which is now easily managed, should be resorted to. If the water distils over acid, neutralize with carbonate of soda. If there

is a little taste from organic matter, let it be exposed to the air for two or three days. Crease's tank-filters supply an excellent means of purifying water in large quantities. The spongy iron ship-filter is also an excellent form of filter for the purpose, and has the further advantage of removing lead, should the water have taken any up during the process of distillation.

During marches each soldier carries a water-bottle.[1] He should be taught to refill it with good water whenever practicable. If the water is decidedly bad, it should be boiled with tea, and the cold tea drunk. The exhausted leaves, if well boiled in water, will give up a little more tannin and coloring matter, and will have a good effect; and if a soldier would do this after his evening meal, the water would be ready for the next day's march. Alum and charcoal should be used. Small charcoal or sandstone filters with elastic tubes (Fig. 4) at the top, which draw water through like siphons, or through which water can be sucked, are useful, and are now much employed by officers. They have been largely used by the French soldiers in Algiers, and some were issued to our troops in the Ashantee campaign. It must be understood that these are all merely strainers, and do not purify the water from dissolved substances.

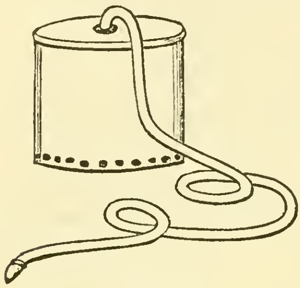

FIG. 4.

Soldiers should be taught that there is danger in drinking turbid water, as they will often do when they are overcome with thirst. Not only all sorts of suspended matters may be gulped down, but even animals. On some occasions, the French army in Algiers has suffered from the men swallowing small leeches, which brought on dangerous bleeding. The pocket filters act fairly well in removing these suspended matters.

If water-carts or water-sacks are used, they should be regularly inspected; every cart should have a straining filter of pure sand, through which the water should pass. The carts and skins should be scrupulously clean. The water-carriers, or bheesties, in India should be paraded every morning, and the sources of water inquired into.

When halting ground is reached, it may be necessary to filter the water. A common plan is to carry a cask, charred inside, and pierced with small holes at the bottom; it is sunk in a small stream, and the water rises through the holes. A better plan still is to have two casks, one inside the other; the outer pierced with holes at the bottom and the inner near the top; the space between is filled with sand, gravel, or any filtering medium that may be procurable; the water rises through the gravel between the barrels, and flows into the inner barrel.[2] The sand, gravel, or other material ought to be frequently turned out, cleaned, or changed. Other simple plans are given in the drawings, which need little description. Figs.

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[1] The Italian water-bottle has been officially adopted in our army, but it is doubtful if it has any advantage except its convenient shape. It certainly imparts an unpleasant taste to the water at first and presents difficulty in cleaning. Probably an iron bottle (coated by the Bower-Barff process), covered with leather, would be better.

[2] In the Zulu campaign Surgeon-General Woolfryes states, that "to the large base hospitals, such as Fort Pearson and Utrecht, large single or double barrel (charcoal) filters made in Pietermaritzburg were furnished. For the troops barrel (sand) filters, made on the spot by the Royal Engineers, were provided."—A. M. D. Reports, vol. xxi., p. 287.

5 and 6 speak for themselves Fig. 7 is a barrel connected by a pipe with a supply above; the water rises through sand and charcoal, and is drawn

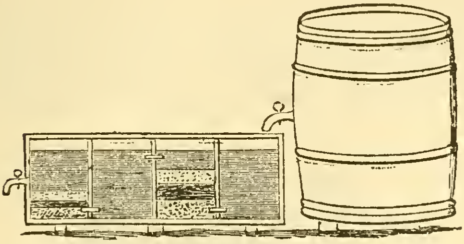

Fig. 5.

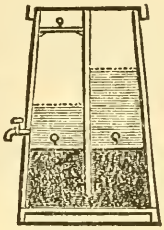

Fig. 6.

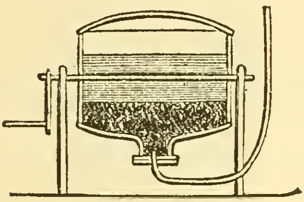

Fig. 7.

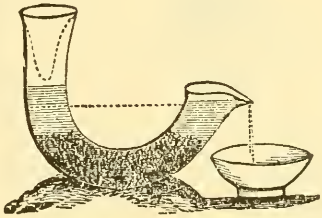

Fig. 8.

out above; the barrel is fixed on a winch, and the supply pipe being removed, and the hole closed, a few turns of the handle clears the sand. Fig.

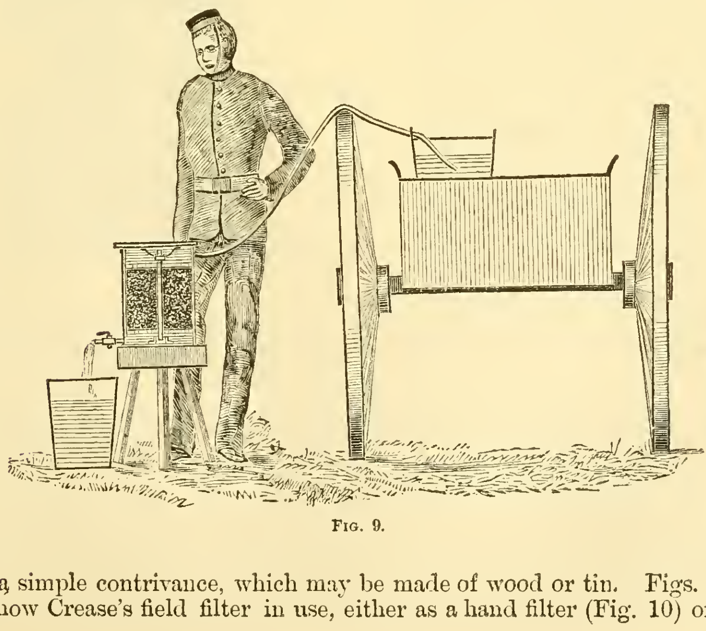

Fig. 9.

8 is a simple contrivance, which may be made of wood or tin. Figs. 9 and 10 show Crease's field filter in use, either as a hand filter (Fig. 10) or con-

nected by an india-rubber tube to a bucket of unfiltered water placed in a cart (Fig. 9). It acts with great rapidity and gives good results.[1]

In the field, the medical officer may be sent on to give a report of the quantity and quality of any source. Before the troops arrive he should make his arrangements for the different places of supply; men and cattle should be watered at different points; places should be assigned for washing; and if removal of excreta by water be attempted, the excreta should

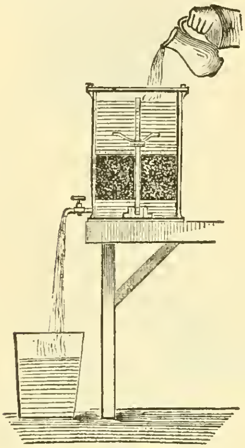

FIG. 10.

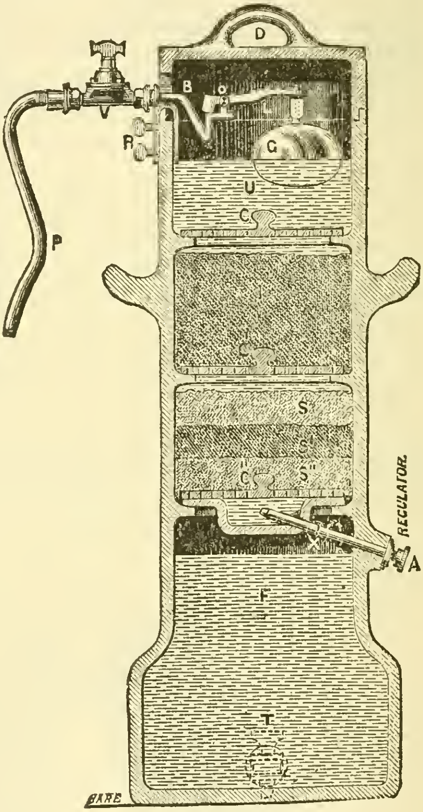

FIG. 11.[2]

flow in far below any possible spring; in the case of a spring, several reservoirs of wood should be made, and the water allowed to flow from one to another—the highest for men, the second for cattle. If it is a running stream, localities should be fixed for the special purpose; that for the men's drinking water should be highest up the stream, for animals below, washing lowest; sentries should be placed as soon as possible. The distribution of water should be regulated; streams are soon stirred up, made turbid, and the water becomes undrinkable for want, perhaps, of simple management.

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[1] In the Zulu campaign of 1879, Surgeon-General Woolfryes reports that "Crease's filters were used in the larger field hospitals, but were found unsuitable for field service, as they would not stand the rough usage incidental to the march."—A. M. D. Reports, vol. xxi., p. 287.

[2] Fig. 11—Spongy iron filter, special ball-cock pattern.—A, cap of regulator; B, ball-cock; C, perforated lid, covering spongy iron; C′, perforated lid, covering *prepared sand;* C″, perforated plate, through which water flows to regulator; D, cover of filter; F, filtered water; G, glass ball; I, spongy iron; L, lever of ball-cock; O, withdrawing-pin of lever; P, tube connecting with water-supply or cistern; R, screws to fasten ball-cock to filter; S, pyrolusite; S′, sand; S″, fine gravel (these three form the *prepared sand*); T, tap or stop-cock, from which to draw the filtered water; U, unfil-

Wherever practicable, the reservoirs or cisterns which are made should be covered in; even if it is merely the most flimsy covering, it is better than nothing.

In sieges the same general rules must be attended to. The distribution of the water should be under the care of a vigilant medical officer. Advantage should be taken of every rainfall; fresh wells should be dug early; if necessary, distillation of brackish or sea-water must be had recourse to.

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tered water; V, screw valve; X, division in regulator, from which X A may be screwed off; near X is the aperture through which the filtered water flows into the reservoir F.

CHAPTER II.

AIR.

It might be inferred from the physiological evidence of the paramount importance of proper aëration of the blood, that the breathing of air rendered impure from any cause is hurtful, and that the highest degree of health is only possible when to the other conditions is added that of a proper supply of pure air. Experience strengthens this inference. Statistical inquiries on mortality prove beyond a doubt that of the causes of death which are usually in action, impurity of the air is the most important. Individual observations confirm this. No one who has paid any attention to the condition of health, and the recovery from disease of those persons who fall under his observation, can doubt that impurity of the air marvellously affects the first, and influences, and sometimes even regulates the second. The average mortality in this country increases tolerably regularly with density of population. Density of population usually implies poverty and insufficient food, and unhealthy work; but its main concomitant condition is impurity of air from overcrowding, deficiency of cleanliness, and imperfect removal of excreta, and when this condition is removed, a very dense and poor population may be perfectly healthy. The same evidence of the effect of pure and impure air on health and mortality is still more strikingly shown by horses; for in that case the question is more simple, on account of the absolute similarity, in different periods or places, of food, water, exercise, and treatment. Formerly, in the French army, the mortality among the horses was enormous. Rossignol[1] states that, previous to 1836, the mortality of the French cavalry horses varied from 180 to 197 per 1,000 per annum. The enlargement of the stables, and the "increased quantity of the ration of air," reduced the loss in the next ten years to 68 per 1,000.[2] In 1862–66 the rate of death was reduced to 27½ per 1,000, and officers' horses (the property of the State) to 20. The admissions for lung diseases were, in 1849–52, 105, and in 1862–66, 36; for glanders, 1847–52, 23; 1862–66, 7½.[3] In the Italian war of 1859, M. Moulin, the chief veterinary surgeon, kept 10,000 horses many months in barracks open to the external air in place of closed stables. Scarcely any horses were sick, and only one case of glanders occurred.[4]

In the English cavalry (and in English racing stables) the same facts are well known. Wilkinson[5] informs us that the annual mortality of cavalry horses (which was formerly great) is now reduced to 20 per 1,000,

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[1] Traité d'Hygiène Militaire. Paris, 1857.
[2] Wilkinson, Journal of the Agricultural Society, No. 50, p. 91 et seq.
[3] Vital Statistics of Cavalry Horses, by T. G. Balfour, M.D., F.R.S., Surgeon-General. Journal of the Statistical Society, June, 1880.
[4] Larrey: Hygiène des Hôp. Mil., 1868, p. 63. [5] Op. cit.

of which one-half is from accidents and incurable diseases. Glanders and farcy have almost disappeared, and if a case occurs, it is considered evidence of neglect.

The food, exercise, and general treatment being the same, this result has been obtained by cleanliness, dryness, and the freest ventilation. The ventilation is threefold—ground ventilation, for drying the floors; ceiling ventilation, for discharge of foul air; and supply of air beneath the horses' noses, to dilute at once the products of respiration.

In cow-houses and kennels similar facts are well known; disease and health are in the direct proportion of foul and pure air.

The air may affect health by variations in the amount or condition of its normal constituents, by differences in physical properties, or by the presence of impurities. While the immense effect of impure air cannot be for a moment doubted, it is not always easy to assign to each impurity its definite action. The inquiry is, in fact, in its infancy; it is difficult, and demands a more searching analysis than has been, or perhaps than can be at present, given. When impure air does not produce any very striking disease, its injurious effects may be overlooked. The evidences of injury to health from impure air are found in a larger proportion of ill health—*i.e.*, of days lost from sickness in the year—than under other circumstances; an increase in the severity of many diseases, which, though not caused, are influenced by impure air; and a higher rate of mortality, especially among children, whose delicate frames always give us the best test of the effect both of food and air. In many cases accurate statistical inquiries on a large scale can alone prove what may be in reality a serious depreciation of public health.

The quantity of air necessary for perfect health will be considered in the chapter on VENTILATION. In the present chapter the impurities will be mentioned, and then the diseases attributable to them.

The following is the composition of average pure air:

Composition of Atmospheric Air.

Oxygen	209.6 per 1,000 volumes.
Nitrogen	790.0 "
Carbonic acid (or carbon dioxide)	0.4 "
Watery vapor	Varies with temperature.
Ammonia	Trace.
Organic matter (in vapor or suspended, organized, unorganized, dead or living),	Variable.
Ozone	Variable.
Salts of sodium	Variable.
Other mineral substances	Variable.

The amount of oxygen is 209.8 in the pure mountain air, while in the air of towns it may fall to 209.0 or 208.7.[1] The mean amount of ozone is given by Levy at 1.15 milligramme per 100 cubic metres at Montsouris.[2]

The amount of watery vapor varies in different countries greatly, from about 30 per cent. of saturation to perfect saturation; or, according to temperature, from 1 to 11, or even 12 grains in a cubic foot of air. During the rains in the tropics, that amount is not unfrequently exceeded. The best ratio for health has not been determined, but it has been sup-

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[1] A. Smith: Air and Rain, pp. 335 et seq.

[2] Annuaire for 1882.

posed it should be from 65 to 75 per cent.; in many healthy climates, however, it is much more and in some much less than this.

The amount of carbon dioxide in normal air ranges from .2 to .5 per thousand (or from 2 to 5 volumes in 10,000); it increases slightly up to 11,000 feet of elevation, then decreases; it is augmented under certain circumstances; as in sea-air by day, though not at night; the difference being between .54 to .33 per thousand (Lewy). During the Arctic Expedition of 1875, Dr. E. L. Moss, of the Alert, found it to range from 0.483 to 0.641 per thousand; mean, 0.552 [1] in N. Lat. 82° 27′.

Fodor [2] found the CO_2 at Buda-Pesth, during the years 1877–8–9, very constant in quantity, the mean being 0.3886 per 1,000 vols. He gives the limits as 0.200 to 0.600, outside which cases occur very seldom, or depend upon errors; the seasonal range is lowest in winter, an increase in spring, again a diminution in summer, and the highest point is reached in autumn. There is less near the sea-shore and more in the middle of the continent; it appears to increase in snow and frost, but to diminish with rain, thaw and wind; the north wind brings less CO_2 with it than the south. Fodor attributes the greatest influence on the variation of CO_2 in the atmosphere to its rising from the ground air; the CO_2 being always greater at the ground level than one metre above it. Levy [3] gives the mean CO_2 at the Observatory of Montsouris at 0.302 per 1,000 vols. in a series of five years' observations.

Ammonia and organic matter ought probably to be considered as impurities.

SECTION I.

IMPURITIES IN AIR.

A vast number of substances, vapors, gases, or solid particles, continually pass into the atmosphere. Many of these substances can be detected neither by smell nor taste, and are inhaled without any knowledge on the part of those who breathe them. Others are smelt or tasted at first; but in a short time, if the substance remains in the atmosphere, the nerves lose their delicacy; so that, in many cases, no warning, and in other instances, slight warning only is given by the senses of these atmospheric impurities.

As if to compensate for this, a wonderful series of processes goes on in the atmosphere, or on the earth, which keeps the air in a state of purity.

Gases diffuse, and are carried away by winds, and thus become so diluted as to be innocuous; or are decomposed if compound, or are washed down by rain; solid substances lifted into the air by winds, or by ascensional force of evaporation, fall by their own weight; or if organic, are oxidized into simple compounds, such as water, carbon dioxide, nitric acid and ammonia; or dry and break up into impalpable particles, which are washed down by rain. Diffusion, dilution by winds, oxidation, and the

[1] Dr. B. Ninnis, of the Discovery, found much higher amounts, but the conditions may not have been quite the same, or some accidental error may have occurred. (See Report of the Committee on the Outbreak of Scurvy, 1877.)

[2] Hygienische Untersuchungen über Luft, Boden u. Wasser, Erste Abtheilung, Die Luft. Braunschweig, 1881. For further details from this important work, see Report on Hygiene, Army Medical Reports, vol. xxiii.

[3] Annuaire de Montsouris, 1882.

fall of rain, are the great purifiers ; and, in addition, there is the wonderful laboratory of the vegetable world, which keeps the carbon dioxide of the atmosphere within certain limits. If it were not for these counterbalancing agencies, the atmosphere would soon become too impure for the human race. As it is, it is wonderful how soon the immense impurity, which daily passes into the air, is removed, except when the perverse ingenuity of man opposes some obstacle, or makes too great a demand even upon the purifying powers of Nature.

The air passing into the lungs in the necessary and automatic process of respiration, is drawn successively through the mouth and nose, the fauces, and the air-tubes. It may consist, according to circumstances, of matters perfectly gaseous (as in pure air), or of a mixture of gases and solid particles, mineral or organic, which have passed into the atmosphere.

The truly gaseous substances will doubtless enter the passages of the lungs, and will meet there with that wonderful surface, covered with the most delicate tufts of blood-vessels, unshielded even, it is supposed by some, by epithelium, which stand up on the surface of 5,000,000 or 6,000,000 air-cells, and through which the blood flows with great velocity ; there they will be absorbed, and if, as has been calculated, the surface of the air-cells is as much as from 10 to 20 square feet (and some have placed these figures much higher), we can well understand the ease and rapidity with which gaseous substances will enter the blood.

The solid particles or molecules entering with the air, may lodge in the mouth or nose, or may pass into the lungs, and there decompose, if of destructible nature ; or may dissolve or break down if of mineral formation ; or may remain as sources of irritation until dislodged ; or perhaps become covered over with epithelium like the particles of carbon in the miner's lung, or may pass into epithelium, and enter the body through the lymphatics.

If such particles lodge in the mouth or nose they may be swallowed, and pass into the alimentary canal, and it is even more probable that this should be the case with all except the lightest and most finely divided substances, than that they should pass into the lungs. Although incapable of present proof, there is some reason to think that some of the specific poisons, which float about in an impure atmosphere, such as those which arise from the typhoid or cholera evacuations, may produce their first effects, not on the lungs or blood, but on the alimentary mucous membrane, with which they are brought into contact when swallowed.

Sub-Section I.—Suspended Matters.

Nature of Suspended Substances.—An immense number of substances, organic and inorganic, may be suspended in the atmosphere. From the soil the winds lift silica, finely powdered silicate of aluminium, carbonate and phosphate of calcium, and peroxide of iron. Volcanoes throw up fine particles of carbon, sand, and dried mud, which, passing into the higher regions, may be carried over hundreds of miles.

The animal kingdom is represented by the débris of the perished creatures who have lived in the atmosphere, and also it would appear that the ascensional force of evaporation will lift even animals of some magnitude from the surface of marsh water.

From the vegetable world pass up seeds and débris of vegetation ; pollen, spores of *fungi*, *mycoderms*, *mucedines*, which may grow in the atmosphere, and innumerable volatile substances or odors. The germs also of

vibriones, bacteria, and *monads* are largely present, and small eggs of various kinds.

From the sea the wind lifts spray, and the chloride of sodium becoming dried is so diffused through the atmosphere, that it is difficult, on spectrum analysis, to find a spectrum without the yellow line of soda.

The works and habitations of man, however, furnish matters probably of much greater importance in a hygienic point of view.

It is not easy at present to give a complete enumeration of all the substances, but the following are the chief facts, divided under the headings of suspended substances in the external air; in rooms inhabited by healthy persons; in rooms inhabited by sick persons; in workshops and factories.

Suspended Substances in External Air.

1. *Dust and Sand Showers.*—In different parts of Europe there occur from time to time showers of dust and sand. Ehrenberg [1] gives the microscopic examination of seventy showers; in addition to particles of sand and oxide of iron, there were numerous organic forms, which are classed by Ehrenberg under the headings of *polygastrica* (194 forms), *phytolithariæ* (145 forms), *polythalmia*, etc. In addition there were portions of plants and fragments of insects. In a dust storm of February, 1872, in Sicily, Silvestri [2] found four species of *diatoms* and living *infusoria.* These sand-storms are sometimes called monsoon showers, but it would appear that any violent storm of a cyclonic character may lift the dust from sandy wastes, as from the African deserts, and transport it great distances.

It remains yet uncertain whether all dust-storms are entirely of telluric origin; it has been supposed that some may be derived from meteoric showers, *i.e.*, may enter our atmosphere from the realms of space, and there has been some speculation as to whether morpholithes of peculiar nature may not be contained in such meteoric dust showers.[3]

There seems no doubt that atmospheric dust may travel to great distances; the air of Berlin has evidently contained organisms derived from the African deserts, and the sails of ships 600 or 800 miles from Africa are often quite red with the sand which lodges on them.

2. Independent of these sand-storms, there are numerous *living creatures* in the atmosphere: some lifted from the ground by winds, others growing in the air. Ehrenberg has discovered at least 200 forms—*rhizopods, tardigrades,* and *anguillulæ.* These can be dried, and will then retain their vitality for months, and even years.

When the external air is examined either by means of an aëroscope of some kind, or by drawing it through previously heated glass tubes, surrounded by a freezing mixture, many of these organisms can be found. Their number cannot be directly estimated at present. Indirectly A. Smith has endeavored to calculate the amount[4] from the ammonia in the air which appears to be derived from organic matter, and has supposed that there might be 529,560 germs (=.0056 grain) in one cubic foot of the air

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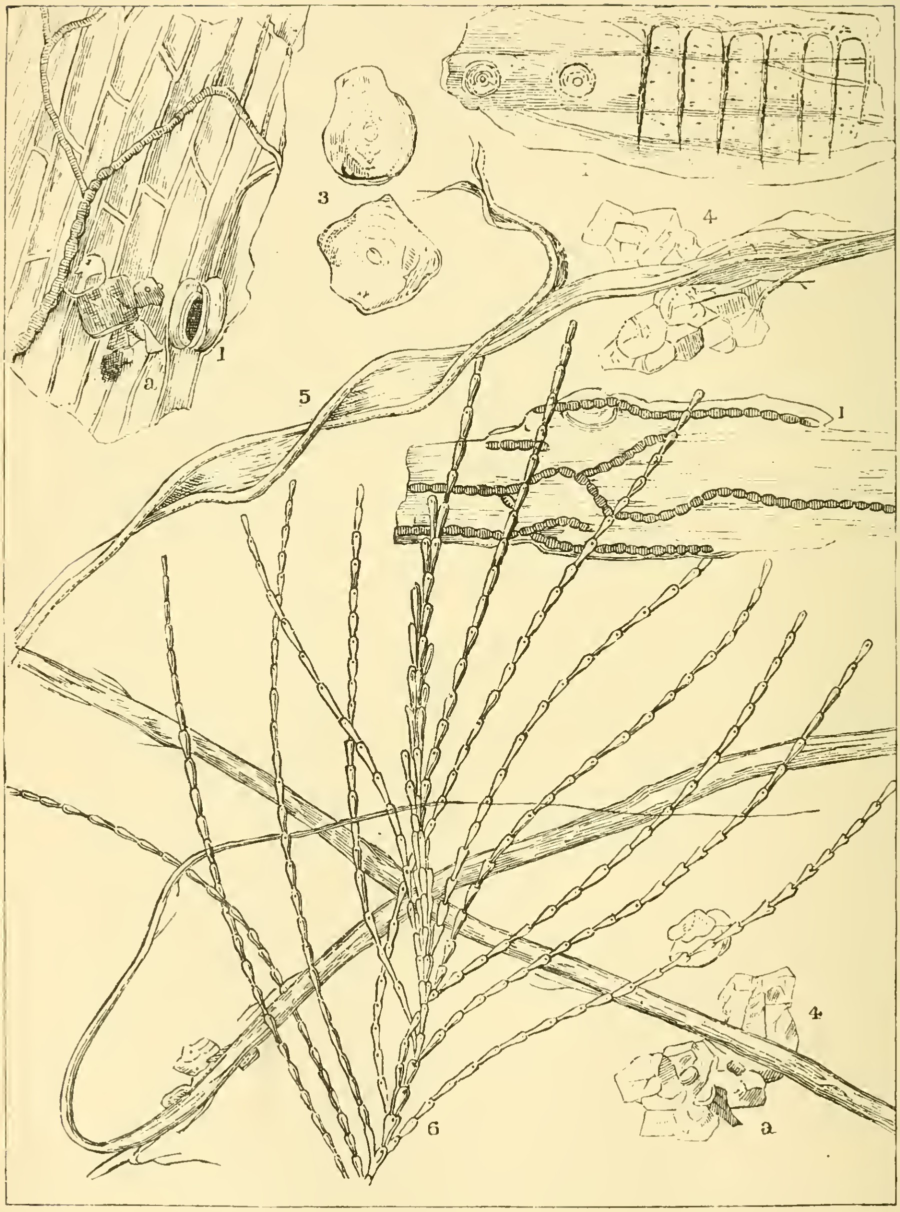
[1] Uebersicht der seit 1847, forgesetzten Untersuchungen über das von der Atmosphere unsichtbar getragene rieche organische Leben. Berlin, 1871.

[2] Comptes Rendus, 1872, p. 991.

[3] Dr. O. Hahn (whose observations are confirmed by D. D. F. Weiland) is said to have discovered organisms of a coralline nature in the interior of meteorites of the choadrite class (Daily Telegraph's Berlin Correspondent, May 13, 1882). Should this prove correct, it opens up a new and interesting field of study, especially in connection with Sir William Thomson's suggestion of the meteoric origin of life in this earth.

[4] Air and Rain, p. 504.

Plate V.



EXTERNAL AIR.

Description of Plate V.

External Air.

Fig. 1. Fragment of Pine-wood.

1′. Epidermis of Hay, with Fungus attached.

2. Linen fibres. *N.B.* The thick fibres crossing in lower third of plate.

3. Epithelium (nucleated) from the mouth.

4. Do. detached from the skin.

5. Cotton fibre.

6′. Feather, or Down.

a. Charred vegetable particles, and mineral matter.

of a city. But indirect calculations of this kind are of course doubtful. The following are the most important kinds :

(*a*) Extremely small round and oval cells, appearing in pairs or adhering together. The cells, described by Lemaire,[1] Trautman,[2] Béchamp, and others, are exceedingly minute, and it requires a power of 600 to 1,000 diameters to see them properly. Trautman states that they grow faster when sulphuretted hydrogen is in the air, and are checked by carbolic acid. Lemaire found them in immense quantities in the air of dirty prison cells, and in the sweat of the prisoners ; they will occur, however, in the open air. They are supposed to increase rapidly by cleavage, but their future development, if any, is uncertain ; no effect on the body has been proved to be produced by them.

These bodies probably correspond to the *micrococci* or *sphærobacteria* of Cohn.

Other *bacteria* are also met with, such as *B. termo* (Microbacteria) *Bacillus* and *vibrio* (Desmobacteria), *Spirillum* and *Spirochæte* (Spirobacteria). Burdon-Sanderson's observations threw doubt on the existence of *bacteria* in the air as such : D. D. Cunningham also found *bacteria* were rarely present (that is, recognizable) in dry atmospheric dust, but they were occasionally found, as well as a specimen of green *spirillum ;* but in the deposit from the moist air of sewers distinct bacteria were frequently observed. The truth probably is that, although they may be rarely met with in full development, this depends on the absence of proper nutriment and favorable conditions for growth, but the existence of their spores (perhaps in some cases the so-called *sphærobacteria*) appears to be clearly proved by the cultivation experiments of Tyndall[3] and Fodor.[4]

The number of *bacteria* also varies with the season (Fodor,[4] Miquel[5]), being greatest in autumn (142) and in summer (105), less in spring (85), and least in winter (49 per metre cube). Part of this variation is due undoubtedly to dryness, for it is observed that in rainy weather they are little to be met with, but after some days of dry weather become plentiful (Nägeli, Fodor, Miquel).

Fodor[4] found at Buda-Pesth, in 1878–79, *bacteria* in 522 out of 646 observations. Drawing the air through a cultivating solution, he found numerous kinds of *bacteria* developed. The *micrococci* or *sphærobacteria* were the most frequent, the *spirobacteria* the rarest. *Desmobacteria* were comparatively rare. One form of *microbacterium* he calls *M. agile*, and attributes to it exceptional infective power. *Monads* were rare.

(*b*) *Spores of fungi* are not infrequent ; in the open air they occur most commonly in the summer (July and August),[6] they are not in this country more frequent with one wind than another ; the largest number found by Maddox in ten hours was 250 spores ; on some days not a spore can be found. Maddox leaves undetermined the kind of *fungus* which the spores developed under cultivation ; the spores were pale or olive-colored and oval, probably from some form of smut. Angus Smith found in water through which the air of Manchester was drawn innumerable spores. Mr.

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[1] Comptes Rendus de l'Acad., Oct., 1867, p. 637.

[2] Die Zersetzungsgase als Ursache zur Weiter-verbreitung der Cholera, 1869.

[3] Floating Matter in the Air in Relation to Putrefaction and Infection, by John Tyndall, F.R.S. Longman, 1881.

[4] Op cit.

[5] Annuaire de Montsouris, 1882, pp. 406 et seq.

[6] Maddox : Monthly Journal of the Microscopical Society, June, 1870, and February, 1871.

Dancer has calculated that in a single drop of the water 250,000 fungoid spores as well as mycelium were present, but as the water was not examined for some time there may have been growth. Mycelium of *fungus* seems uncommon in the air, but is sometimes found. The cells of the *Protococcus pluvialis* are not uncommon, and perhaps of other *algæ*. Blackley [1] says the amount of spores collected on a slide in four hours amounted to 30,000 or 40,000 per square inch. Dr. D. D. Cunningham[2] states that in the air in the suburbs of Calcutta spores are constantly present, and usually in considerable numbers. He gives a large number of beautiful drawings.

Fodor[3] found by cultivation that *mucedines* made their appearances 171 times, *sarcinae* 48. *Bacteria* and *fungi* seemed to alternate in seasons and years. Thus in spring *bacteria* were most numerous and *fungi* fewest, whilst the opposite was the case in autumn. Snow and rain lessened the quantity of both.

(*c*) *Parts of flowers*, especially *pollen*,[4] in the spring and summer are very common,—cuticular scales, vegetable fibres and hairs, seed capsules, globular cells, etc. Near habitations are also found bits of wood often withered or burnt, bits of charcoal, starch grains, cotton and wool fibres, etc. All these substances appear from Watson's experiments to be more abundant in land than sea air, as might, indeed, be expected.[5]

(*d*) *Animals*, or portions, such as scales from the wings of moths and butterflies; portions of the wings of insects; legs of spiders, bits of spiders' webs, and similar objects, are not uncommon; but sometimes even living animals of some size, apparently rhizopods and amœbiform bodies.

(*e*) *Mineral substances*, fine particles of sand, clay, and chalk are generally met with, even when there is no dust-storm, and are much more common when the ground is dry; rain, indeed, appears not only to prevent these particles from being lifted, but also to precipitate those in the air.

In manufacturing districts, or near a railway, there may be even large particles of metals, or pottery clay, or stone in the external air; in the dust collected from a railway carriage near Birmingham, Mr. Sidebotham [6] found many large particles of iron capable of attraction by a magnet, and being, in fact, fused particles of iron often covered with spikes and excrescences.

In towns with macadamized roads, dust and remains of horse droppings, finely powdered by the traffic, pass into the air, and as this is more common in dry weather, the sanitary importance of watering and washing the streets of great traffic is manifest.

Mr. Tichborne has published[7] some analyses of the street dust of Dublin; it contained from 29.7 per cent. of organic matter (at the top of a pillar 134 feet high) to 45.2 per cent. (in the air of a street); the organic matter was chiefly stable manure finely ground; it acted as a ferment, and

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[1] Experimental Researches on the Causes and Nature of Catarrhus Æstivus, 1873.

[2] Ninth Annual Report of the Sanitary Commissioner with the Government of India.

[3] Op. cit.

[4] Blackley (op. cit.) shows that pollen is in large quantities, sometimes amounting to 7,870 grains per square inch of slide. In the upper strata of the air (at 400 to 500 feet) he found much more than in the lower, on an average 19 times as much. Cunningham (op. cit.) also found pollen in large quantity.

[5] Army Medical Department Report, vol. xi., p. 529 (1871).

[6] Chemical News, October, 1871.

[7] Ibid., October, 1870.

Description of Plate VI.

Accident Ward.

Fig. 1′. Epidermis of Hay. 1. Do. with Fungus attached.

2. Linen fibre.

2′. Fungus filament. *N.B.* Long narrow filament in upper left of plate.

3. Nucleated Epithelium from the mouth.

3*a*. Pus cells.

4. Worn Epithelium from the skin.

4*a*. Charred vegetable particles. 4*d*. Fungus spores.

5. Cotton fibre.

6. Woollen fibre.

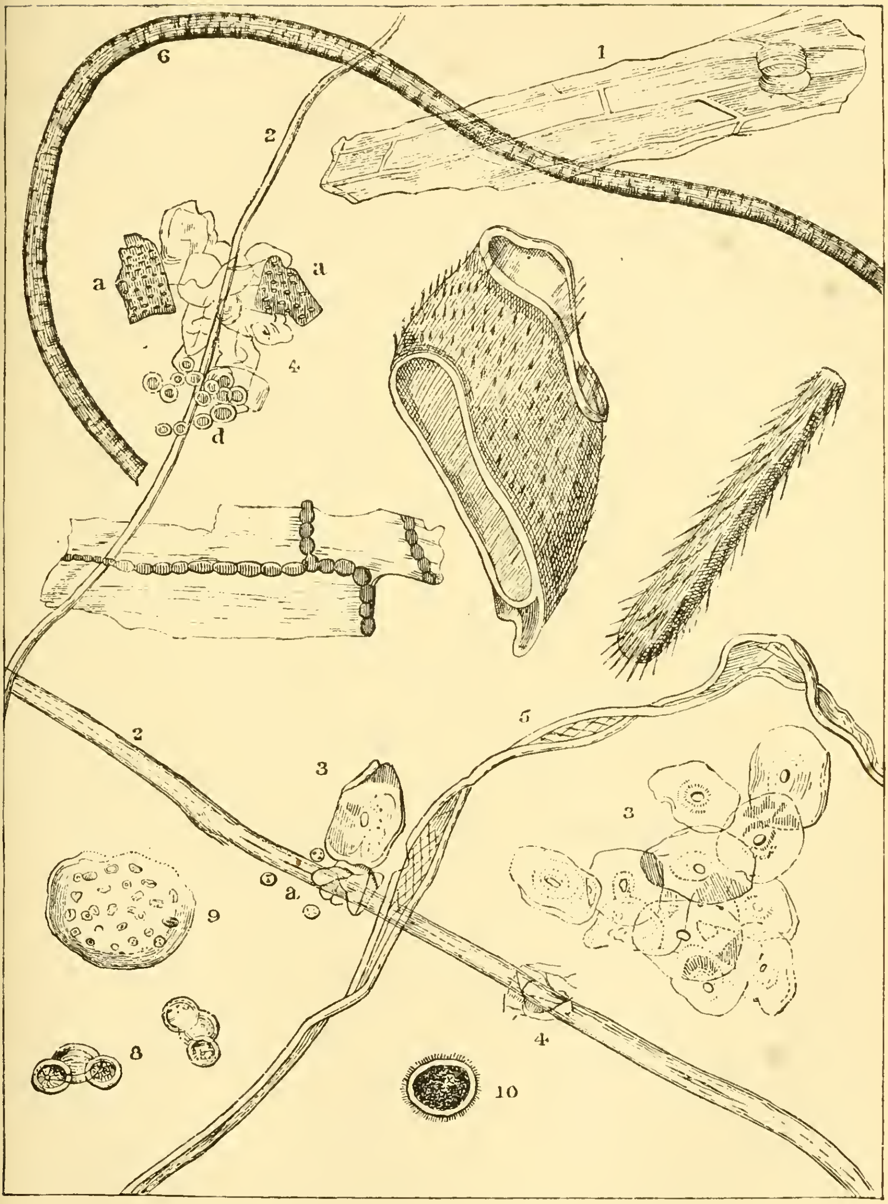
7. Fragments of Insects.

8. Pine Pollen.

9. Dried-up Palmellaceous Frand.

10. Ciliated spore, probably of *Vaucheria*.

Plate VI.



ACCIDENT WARD. ST. MARY'S HOSPITAL, LONDON.

reduced nitrate of potassium into nitrite ; it had, therefore, a strong deoxidizing power. The plate (No. V.) drawn by Dr. J. D. Macdonald, R.N., F.R.S., shows some of the substances collected from the external air in the garden of St. Mary's Hospital, Paddington.[1]

(*f*) It cannot be doubted that various organic substances dried in the ground and finely pulverized, may be lifted into the air by winds, and may be carried to great distances ; under the microscope the particles would probably appear formless, and could not be referred to any special class, but would be included under the term of "dust," or "amorphous matter." In this way it is believed that some diseases may be propagated ; cholera, for example, by the particles of dried excreta lifted and carried by the wind, and small-pox and scarlet fever by the disintegrated epidermis or dried discharges.[2]

Some of the various particles of different kinds thus suspended in the air reflect and scatter the rays of light, and produce the appearance of fine motes, which are familiar to every one, as seen in the course of a ray of light passing through a dark room, or when an electric beam is transmitted through a tube. When the air is kept motionless they subside, so that most of them have some weight, though some are so light as to float in rarefied air (Tichborne) ; when heated, Tyndall has shown that many of them are burnt, and a little bluish mist arising from the combustion can even be perceived ; the destructible nature proves, of course, the organic origin of those consumed, but does not show whether they are organized or not.

Suspended Matters in Enclosed Spaces.

1. *Rooms inhabited by Healthy Persons.*—In all inhabited rooms which are not perfectly ventilated, the presence of scaly epithelium, single and tessellated ; round cells like nuclei, portions of fibres (cotton, linen, wool), portions of food, bits of human hair, wood, and coal, can be found in addition to the bodies which are present in the external air, though, as pointed out by Watson, mineral matters and vegetable matters are not so plentiful, as the comparative stillness of the air allows them to fall.[3]

In some cases articles of furniture may furnish certain substances ; the flock wall-papers, colored green by arsenical preparations (especially Scheele's green and Schweinfürth green), give off little particles of arsenical dust into the room ;[4] and it has been shown by Professor Fleck[5] that the arsenious acid in the Schweinfürth green, when in contact with moist organic substances, and especially paste or size, forms arseniuretted hydrogen,[6] which diffuses in the room, and is no doubt the cause of some of the cases of arsenical poisoning from green papers.

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[1] From Three Reports on the Sanitary Condition of St. Mary's Hospital, Paddington, by Surgeon-Major F. de Chaumont, M.D., 1875–76.

[2] In the air of the back-yard of another London hospital, I found considerable quantities of epithelium ; and in the "dirty linen area," where the foul linen was kept in crates till washed, I found not only epithelium, but even pus globules, and also a quantity of fatty crystals, apparently from dressings. There were also *bacteria*, both free and in the zooglæal form.—[F. de C.]

[3] Numerous observations on the air of barracks and military hospitals have been made by medical officers of the army, especially by Drs. de Chaumont, Frank, Hewlett (of Bombay), Stanley, Baynes Reed, Venner, Watson, and many others. (See the Army Medical Department Annual Reports, from 1860–70.)

[4] Halley and many others.

[5] Zeitsch. für Biologie, Bd. viii., p. 445 (1872).

[6] Perhaps other substances are also formed, such as cyanide of kakodyle, which is intensely poisonous (Bartlett).

Sick-Rooms.—In addition to being vitiated by respiration, the air of sick-rooms is contaminated by the abundant exhalations from the bodies, and by the effluvia from discharged excretions. The quantity of organic matter is known to be large, but it is difficult at present to give a quantitative statement. Moscati, who (in 1818) condensed the watery vapor of a ward at Milan, describes it as being slimy, and as having a marshy smell. The peculiar smell of an hospital is indeed very remarkable, and its similarity in hospitals of different kinds seems to show that the odorous substance has a similar composition in many cases. The reaction of ozone is never given in such an atmosphere.

Devergie found an "immense amount" of organic matter in the air in the vicinity of a patient with hospital gangrene.

The dust of a ward in St. Louis, in Paris, examined by Chalvet, was found in one experiment to contain 36 per cent. of organic matter, and in another 46 per cent. When burnt, it gave out an odor of horn. The dust collected in hospitals for diseases of the skin is stated by Gailleton to be full of sporules of *Trichophyton.* They can be found in the air of the ward when condensed by ice.

Much interest was excited in 1849 by the discovery by Drs. Brittan and Swayne, of Clifton, of bodies very like *fungi* in the air of a cholera ward; later researches lead to the opinion that this observation was perfectly correct, though the connection between these *fungi* and cholera is still quite uncertain. In 1849, also, Dr. Dundas Thomson drew the air of a cholera ward through sulphuric acid; various suspended substances were arrested, starch, woollen fibres, epithelium, *fungi* or spores of *fungi*, and *vibriones.* Mr. Rainy also found in the air of a cholera ward in St. Thomas' Hospital, the spores and mycelium of *fungi* and *bacteria.* Some of these bodies were found, however, in the open air. In hospitals for skin diseases *Achorion* has been detected in the air where there are patients with *favus;* and Tilbury Fox[1] has figured the spores (clustered and in chains), and the mycelium of *Trichophyton* in a ward with a number of children with *tinea circinata.*

In a ward in Netley Hospital (under Brigade-Surgeon Veale, A.M.D.), where repeated cases of erysipelas occurred, the air was found to be loaded with *fungi.* The ward being emptied, and the floor, walls, and ceiling being washed with carbolic acid, the disease ceased.

The scaly and small round epithelia found in most rooms are in large quantity in hospital wards; and probably in cases where there is much expectoration or exposure of pus or puriform fluids to the air, the quantity would be still larger.

Considering that the pleuro-pneumonia of cattle is probably propagated through the pus and epithelium cells of the sputa passing into the air-cells of other cattle; that even in man there is evidence of a pneumonic or phthisical disease being contagious,[2] the floating of these cells in the air is worthy of all attention. It may explain some of those curious instances of phthisis being apparently communicated. In the air of a phthisical ward at Netley, Dr. Watson not only found pus-cells, but bodies which were not found in the external air or in the rooms of healthy persons, and which were very like the cells seen in tuberculous matter. In military granular conjunctivitis (gray granulations), the remarkable effect of ventilation in arresting the spread (Stromeyer) seems to show that we

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[1] Lancet, January, 1872.

[2] Bryson, Cases in the Mediterranean Fleet.

have here a similar case, and that ventilation acts by diluting, oxidizing, and drying the cells thrown off from the conjunctivæ. In small-pox wards, Bakewell has found unequivocal evidence of minute scales of small-pox matter in the air. It seems probable that the discovery of suspended matters of this kind will lead to most important results.[1] The possibility of a direct transference from body to body of cells undergoing special chemical or vital changes is thus placed beyond doubt, and the doctrine of contagion receives an additional elucidation. It is now generally admitted that protophytes like *Protococcus pluvialis*, may be dried, and yet retain their vitality even for years, and may be blown about in atmospheric currents ; and should contagion be proved to depend upon minute organisms these might easily be carried about in a similar way, either alone or carried by epithelium or other particles thrown off from the bodies of patients. The success which has sometimes attended the treatment of pleuro-pneumonia in cattle by means of carbolic acid (Crookes), and the apparent advantage of inhaling disinfectants in human phthisis, seem to point to a similar active cause in those maladies ; and this appears in some sort confirmed by the observation of Koch on the supposed *bacillus* of phthisis.

3. *Workshops, Factories, and Mines.*—Grinding of steel and iron, and stones ; making metallic and pearl buttons ; melting zinc ; melting solder ; carding and spinning textile fabrics of all kinds ; grinding paint ; making cement, and in fact almost innumerable trades cause more or less dust, derived from the fabrics and materials, to pass into the air.

Dr. Sigerson[2] found a black dust composed of carbon, iron (in the shape of small jagged pieces and also as hollow balls $\frac{1}{2000}$ of an inch in diameter), and ash, in metal shops. In the air of a printing-office there was enough antimony to be chemically detected. In the air of stables were equine hairs, epithelium, moth-cells, ovules, and various fungi.

In addition to these suspended matters, which vary with the kind of work, the air of workshops is largely contaminated by respiration and by the combustion of gas.

In mines the suspended matters are made up of the particles of the particular substance which is being worked, or of rock excavated to obtain metals, of sooty matters from lamps and candles, and of substances derived from blasting.

Sub-Section II.—Gaseous Substances.

A great number of gases may pass into the atmosphere either from natural causes or from the works of man.

Compounds of Carbon.—Carbon dioxide (abnormal if exceeding 5 in 10,000 parts), carbon monoxide, carburetted hydrogen or methane, and peculiar substances (gaseous) in sewer air.

Compounds of Sulphur.—Sulphur dioxide, sulphuric acid, hydrogen sulphide, ammonium sulphide, and carbon disulphide.

Compounds of Chlorine.—Hydrochloric acid from alkali works.

Compounds of Nitrogen.—Ammonia and ammonium acetate, sulphide,

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[1] In the accident ward of St. Mary's Hospital, Paddington, I found pus-cells in the air, near some beds which had a bad reputation for erysipelas. See plate drawn by Dr. Macdonald (Report on St. Mary's, op. cit.).—[F. de C.]

[2] British Medical Journal, June, 1870, from Memoirs of the Irish Academy, in which publication are some excellent observations by the same writer.

and carbonate (normal in small amount?), and nitrous and nitric acids.

Compounds of Phosphorus.—Hydrogen phosphide.

Organic Vapors.—Of the exact composition of the vapors, often fetid, which arise from various decomposing animal matters, little is known.

Sub-Section III.—Nature of Impurities in certain Special Cases.

Air Vitiated by Respiration.

An adult man, in a state of repose, gives off in twenty-four hours from 12 to 16 cubic feet or more, according to weight, of carbon dioxide, the most of it from the lungs, although he also emits an undetermined quantity by the skin. On an average, an adult man, not doing excessive work, may be considered to give to the atmosphere every hour not less than .6 cubic foot of carbonic acid. Pettenkofer states the amount at about 0.7.[1] Women give off less, and children and old people also give off a smaller amount.

The amount of carbonic acid in pure air being assumed to be on an average 0.4 per 1,000, or four volumes per 10,000, the quantity in the air of the rooms vitiated by respiration varies within wide limits, and many analyses will be found in books. The following table is a part of the numerous experiments on barrack-rooms by Dr. de Chaumont on this point, and is especially valuable, because the amount of CO_2 in the external air was simultaneously determined. The analyses were made at night, when the men were in the rooms. The cubic space per head was 600 feet in the barracks and from 1,200 to 1,600 in the hospitals.

The last column of the table shows the condition of the ventilation as measured by the CO_2; it is very satisfactory in the new barracks (Gosport and Chelsea), but is much less so in the old barracks and casemates. The Herbert and Hilsea military hospitals show excellent ventilation, while the old-fashioned Portsmouth garrison hospital is in this respect very bad. The prison-cells show, in all cases, a very high degree of respiratory impurity, and this must be one of the depressing influences of long cell confinement. Wilson[2] gives some important information on this point. In cells (in Portsmouth Convict Prison) of 614 cubic feet, always occupied, he found the $CO_2 = 0.720$ per 1,000; the prisoners were healthy and had a good color. In cells of 210 cubic feet, occupied only at night by prisoners employed outside during the day, he found 1.044 per 1,000 of CO_2; the occupants were all pale and anæmic.

The carbonic acid of respiration is equally diffused through the air of a room (Lassaigne, Pettenkofer, Roscoe); it is very rapidly got rid of by opening windows, and in this respect differs from the organic matter, and probably from the watery vapor; neither appears to diffuse rapidly or equably through a room.

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[1] This is the quantity adopted by Roth and Lex (Militär-Gesundheitspflege).

[2] Handbook of Hygiene.

Amount of Carbon Dioxide in 1,000 Volumes of Air (de Chaumont).

	CO_2 in External Air.	CO_2 in Room.		Mean Respiratory Impurity.
		Largest Amount found.	Mean Amount.	
BARRACKS.				
Gosport New Barracks	.430	1.846	.645	.215
Anglesey Barracks	.393	1.971	1.404	1.011
Aldershot	.440	1.408	.976	.536
Chelsea	.470	1.175	.718	.248
Tower of London	.420	1.731	1.338	.898
Fort Elson (Casemate)	.425	1.874	1.209	.784
Fort Brockhurst (Casemate)	.422	1.027	.838	.416
MILITARY AND CIVIL HOSPITALS.				
Portsmouth Garrison Hospital	.306	2.057	.976	.670
Portsmouth Civil Infirmary	.322	1.309	.928	.606
Herbert Hospital	.424	.730	.472	.048
Hilsea Hospital	.405	.741	.578	.173
St. Mary's, Paddington	.560	1.534	.847	.287
MILITARY AND CIVIL PRISONS.				
Aldershot Military Prison—Cells	.409	3.484	1.651	1.242
Gosport Military Prison—Cells	.555	2.344	1.335	.780
Chatham Convict Prison—Cells	.452	3.097	1.691	1.239
Pentonville Prison—Cells—Jebb's system	.420[1]	1.926	.989	.569

The amount of CO_2 is often much greater than in the above instances. In a boys' school with 67 boys, and 4,640 cubic feet (=69 cubic feet per head), Roscoe found 3.1 parts of CO_2 per 1,000. In Leicester, in a room with six persons, and only 51 cubic feet of space per head, and with three gas-lights burning, Mr. Weaver[2] found the CO_2 to be 5.28 parts per 1,000; while, in a girls' school-room (70 girls, and 10,400 cubic feet), or 150 cubic feet per head, Pettenkofer found no less than 7.230 parts per 1,000. In many schools, work-rooms, and factories, the amount of respiratory impurity must be as great as this, and doubtless a constant unfavorable effect is produced on health. Dr. Hayne (in H.M. ship Doris) found the CO_2 to range from 1.03 to 3.21 between decks, the latter quantity being in the ward-room with the scuttles in.[3] In the Arctic Expedition of 1875–76, Dr. Moss found as much as 4.82 in the ward-room of the Alert, "room feeling very close;" and Dr. Ninnis found 5.57 in the lower deck of the Discovery.

Gärtner[4] found in the armored corvette Jackson, about 1.0 between decks, as much as 6.42 in the sick-bay, 5.54 in the cells, and no less than 50 in the powder magazines.

In a horse stable at the École Militaire, the amount was 7 per 1,000. At Hilsea, with a cubic space of 655 cubic feet per horse, the amount was 1.053;

[1] Assumed at .420.

[2] Mr Weaver gives several good analyses in different public and private rooms in Leicester. Lancet, July and August, 1872.

[3] Med. Chir. Trans., vol. lvii.

[4] Deutsche Vierteljahrschrift für Offentliche Gesundheitspflege, Bd. xiii., p. 369, 1881.

and in another stable, with 1,000 cubic feet per horse, only .593 per 1,000 (de Chaumont). Märcker found 8.5 in a stable in Gottingen, and no less than 17.07 in a byre.

By the skin and lungs pass off from 25 to 40 ounces of water in twenty-four hours, to maintain which, in a state of vapor, 211 cubic feet of air per hour are necessary on an average. Of course, however, temperature and the hygrometric condition of the air greatly modify this. Organic matter is also given off from the skin and lungs, the amount of which has never been precisely determined. Nor is it possible, at present, to estimate it correctly. This organic matter must be partly suspended, and is made up of small particles of epithelium and fatty matters detached from the skin and mouth, and partly of an organic vapor given off from the lungs and mouth. The organic matter from the lungs, when drawn through sulphuric acid, darkens it; through permanganate of potash, decolorizes it; and through pure water, renders it offensive. Collected from the air by condensing the watery vapor on the sides of a globe containing ice (as by Taddei in the wards of the Santa Maria Novella), it is found to be precipitated by nitrate of silver, to decolorize potassium permanganate, to blacken on platinum, and to yield ammonia. It is therefore nitrogenous and oxidizable. It has a very fetid smell, and this is retained in a room for so long a time, sometimes for four hours, even when there is free ventilation, as to show that it is oxidized slowly. It is probably in combination with water, for the most hygroscopic substances absorb most of it. It is absorbed most by wool, feathers, damp walls, and moist paper, and least by straw and horse-hair. The color of the substance influences its absorption in the following order: black most, then blue, yellow, and white. It is probably not a gas, but is molecular, and floats in clouds through the air, as the odor is evidently not always equally diffused through a room. In a room, the air of which is at first perfectly pure, but is vitiated by respiration, the smell of organic matter is generally perceptible when the CO_2 reaches .7 per 1,000 volumes, and is very strong when the CO_2 amounts to 1 per 1,000.[1] From experiments made at Gravesend, Netley, Aldershot, and Hilsea, by various medical officers,[2] it has been shown that the amount of potassium permanganate destroyed by air drawn through its solution is generally in proportion to the amount of CO_2 of respiration.

When the air of inhabited rooms is drawn through pure water, and the free ammonia got rid of, distillation with alkaline permanganate, in the method of Wanklyn, gives a perceptible quantity of "albuminoid ammonia." In a bedroom at 9 P.M., A. Smith[3] found .1901 milligramme in 1 cubic metre of air; at 7 A.M., there were .3346 milligramme in each cubic metre.

The average of eight observations in the external air (at Portsmouth) gave 0.0935 of free NH_3, and 0.0886 of albuminoid NH_3 in milligrammes per cubic metre. In the Portsmouth General Hospital the free NH_3 was as high as 0.855, and the albuminoid 1.307.[4]

The following is from Dr. de Chaumont's Reports on the Ventilation Experiments at St. Mary's Hospital, Paddington:

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[1] On this point see table at page 159.

[2] See note, p. 119.

[3] Air and Rain, p. 436.—If expressed as grammes per million cubic meters, the amount is 190.114 and 334.601; in grains, in one million cubic feet, the numbers are 83.074 and 146.210.

[4] Moss, Lancet, November, 1872.

Milligrammes per Cubic Metre.

	Free NH_3.	Albuminoid NH_3.	Organic Oxygen.	Total Oxygen for oxidizable matter.	Remarks.
External air, July, 1875.....	0.3574	0.5280	....	1.4300	Air damp and still, wind S.W., slight.
Wards........	0.6680	0.4710	....	1.4900	
Do.	0.6669	0.6770	....	1.5100	
Do.	0.3519	0.6915	....	1.3600	
External air, August, 1876...	0.0163	0.5206	0.4444	0.5714	Air dry and warm, wind S.E. by E., fresh.
Wards.........	0.0497	0.4622	0.3747	0.5621	
Do.	nil.	0.2824	0.2571	0.5142	
Do.	0.0310	0.3576	0.3101	0.3567	
Do.	0.0127	0.5259	0.2225	0.4451	
Do.	0.0100	0.3684	0.4420	0.6315	

It is evident that the condition of the external air, with regard to movement and humidity, has a great deal to do with the amount of organic matter. The nitrogen acids are also met with ; in one instance, in the above experiments, they reached in a ward 28.484 per metre, of which 0.7392 was nitrous, and the rest nitric acid.

Air vitiated by Combustion.

The products of firing pass out into the atmosphere at large ; those of lighting are for the most part allowed to diffuse in the room.

Coal of average quality gives off in combustion :

1. *Carbon.*—About 1 per cent. of the coal is given off as fine carbon and tarry particles.

2. *Carbon dioxide.*—In Manchester, Angus Smith calculated some years ago that 15,000 tons of carbon dioxide were daily thrown out, and the quantity must now be still larger. In London over 30,000 tons of coal a day are consumed, and this would yield nearly 90,000 tons of carbon dioxide.

3. *Carbon monoxide.*—The amount depends on the perfection of combustion.

4. *Sulphur, sulphur dioxide,* and *sulphuric acid.*—The amount of sulphur in coal varies from ½ to 6 or 7 per cent. In the air of Manchester, A. Smith found 1 grain of sulphuric acid in 2,000 and 1,076 cubic feet.

5. *Carbon disulphide.*

6. *Ammonium sulphide* or *carbonate.*

7. *Hydrogen sulphide* (sometimes).

8. *Water.*

From some manufactories there pour out much greater quantities of SO_2 (copper works), arsenical fumes, hydrogen sulphide, carbon dioxide, etc.

For complete combustion 1 ℔ of coal demands about 240 cubic feet of air.

Wood produces carbon dioxide and monoxide and water in large quantity, but few compounds of sulphur. 1 ℔ of dried wood demands about 120 cubic feet of air for complete combustion.

Coal-gas, when fairly purified, is composed of—

Hydrogen	40	to	45.58
Marsh gas (light carburetted hydrogen)	35	to	40
Carbon monoxide	3	to	6.6
Olefiant gas (ethylene or ethene)	3	to	4
Acetylene (or ethine)	2	to	3
Hydrogen sulphide	0.29	to	1
Nitrogen	2	to	2.5
Carbon dioxide	3	to	3.75
Sulphur dioxide }	.5	to	1
Ammonia or ammonium sulphide }	(or in the best cannel-		
Carbon disulphide }	coal gas only traces).		

In some analyses the carbon monoxide has been as high as 11 per cent., and the light carburetted hydrogen 56; in such cases the amount of hydrogen is small. As much as 60 grains of sulphur have been found in 100 cubic feet of gas.[1] The parliamentary maximum is 20 grains in 100 cubic feet. In badly purified gas there may be a great number of substances in small amount, especially hydrocarbons and alcohols, such as propylene, butylene, amylene, benzole, xylol, some of the nitrogenous oily bases, such as pyrrol, picoline, etc.[2]

When the gas is partly burnt, the hydrogen and light and heavy carburetted hydrogens are almost destroyed; nitrogen (67 per cent.), water (16 per cent.), carbon dioxide (7 per cent.), and carbon monoxide (5 to 6 per cent.), with sulphur dioxide and ammonia, being the principal resultants. And these products escape usually into the air of rooms. With perfect combustion there will be little carbon monoxide.

According to the quality of the gas, 1 cubic foot of gas will unite with from .9 to 1.64 cubic foot of oxygen, and produces on an average 2 cubic feet of carbon dioxide, and from .2 to .5 grain of sulphur dioxide. In other words, 1 cubic foot of gas will destroy the entire oxygen of about 8 cubic feet of air. One cubic foot of gas will raise the temperature of 31,290 cubic feet of air 1° Fahr.

Oil.—A lamp with a moderately good wick burns about 154 grains of oil per hour, consumes the oxygen of about 3.2 cubic feet of air, and produces a little more than ½ a cubic foot of carbon dioxide; 1 ℔ of oil demands from 140 to 160 cubic feet of air for complete combustion.

A candle of 6 to the ℔ burns per hour about 170 grains.

The products of the combustion of coal and wood pass into the atmosphere, and usually are at once largely diluted. Diffusion and the ever-moving air rapidly purify the atmosphere from carbon dioxide.

It is not so, however, with the suspended carbon and tarry matters, which are too heavy to drift far, or to ascend high. As a rule, the particles of carbon are not found higher than 600 feet; and the way it accumulates in the lower strata of the atmosphere can be seen by looking at any lofty building in London. The air of London is so loaded with carbon, that even when there is no fog, particles can be collected on Pouchet's aëroscope when only a very small quantity of air is drawn through.

It is apparently chiefly from combustion, and in some cases from chemical works, that the air of towns contains so much acid as to make

[1] Chemical News, March, 1865, p. 154

[2] For a further list of these substances, which do not appear very important, see Pappenheim's Handbuch der San. Pol., Band iii., Supp., p. 261.

rain water acid. In Manchester, in 1868, Angus Smith found the rains to contain from 5.6 grains to 1.4 grain of sulphuric acid (free and combined), and from 1.277 to .0287 grain of hydrochloric acid per gallon. In Liverpool and Newcastle air the same thing occurs ; the sulphuric acid is always larger in amount than the hydrochloric.

Sulphurous and sulphuric acids also appear to be less rapidly removed, as Angus Smith found a perceptible quantity in the air of Manchester ; and the rain water is often made acid from this cause.

The products of gas combustion are for the most part allowed to escape into rooms, but certainly this should not be allowed, when gas is burnt in the large quantities commonly used. The immense quantity of gas often used causes great heat, humidity of the air, and there is also some sulphur dioxide, an excess of carbon dioxide, and, probably, a little carbon monoxide, to which some of the effects may be due. Weaver [1] found as much as 5.32 volumes of carbon dioxide per 1,000 in the room of a frame-work knitter in Leicester, with 14 gas lights burning. In other work-rooms the amounts were 5.28, 4.6, down to 2.11 volumes per 1,000. This amount has a very injurious effect on health, as shown long ago by Dr. Guy. In a workshop in Paris, with 400 men and 400 gas-burners, the health of the men was very bad. General Morin introduced good ventilation, and the number of cases of illness was reduced one-third. The appetite of the men, formerly very bad, greatly improved. According to Dr. Zock,[2] coal-gas gives off rather more carbon dioxide for an equal illuminating power than oil, but less than petroleum. Dr. Odling found for equal illuminating power, that candles gave more impurity to the air than gas.[3] Gas gives out, however, more water.

In tobacco smoke are contained particles of nicotine or its salts (Heubel), and probably of picoline bases. There is also much carbon dioxide, ammonia, and butyric acid.

Dr. Ripley Nichols has investigated the air in smoking cars on American railways, and found the CO_2 to range from 0.98 to 3.35 per 1,000, with a mean of 2.278 : in ordinary non-smoking cars the CO_2 varied from 1.74 to 3.67, with a mean of 2.32, so that there was not much difference as far as CO_2 went. As regards ammonia, however, the difference was great, for (taking the external air ratio as 100) he found in the smoking car from 310 to 575, whilst in the ordinary cars it was only 135 to 175. None of the peculiar products of the combustion of tobacco were found.[4]

Air vitiated by Effluvia from Sewage Matter and Air of Sewers.

Air of Cesspools.—The air of cesspools, and especially of the cemented pits which are still common in many continental towns, and which receive little beyond the solid and liquid excreta and some of the house water, is generally highly impure. Lévy [5] refers to an extreme case, in which the oxygen was lessened to 2 per cent., the nitrogen being 94 and the CO_2 4. In this case apparently no other gases were present ; but in most instances there is a variable amount of hydrogen sulphide[6], ammonium sulphide, nitrogen, carbon dioxide, and carburetted hydrogen, in addition to fetid

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[1] Lancet, July, 1872.
[2] Zeitsch. für Biol., Band ii., p. 117 (1866).
[3] Medical Times and Gazette, January 9, 1869.
[4] Reprint from the Sixth Annual Report of the Massachusetts Board of Health.
[5] Traité d'Hygiène, 3d edit , p. 636.
[6] Barker, On Malaria and Miasmata, p. 245.

organic matters. These organic matters are in large amount; 62 feet of the air of a cesspool destroyed, in Angus Smith's experiments, as much potassium permanganate as 176,000 cubic feet of pure air, though perhaps some hydrogen sulphide may have been also present. Oesterlen[1] states that these gases will pass easily through walls; and M. Hennezel[2] noticed that in the "fosses d'aisances" in Paris, even in those covered with stone slabs and earth, the wind blowing down the ventilating tube will force the gas through the neighboring walls, and then perhaps into the house.

The Air of Sewers.—In sewers the products of decomposition are variable, as not only solid and liquid excreta and house water, but the washings and débris of the streets, the refuse of trades, etc., pass into the sewers. As a rule, the products of decomposition of the sewer water appear to be much the same as noted above—viz., fetid organic matters, carbo-ammoniacal substances condensing with the water of the air on the cold walls, carbon dioxide, nitrogen, and hydrogen sulphide.[3] The proportions of these gases are variable;[4] the most common are carbon dioxide and nitrogen; marsh gas is found when oxidation is impeded, and hydrogen sulphide and ammonium sulphide, which form in the sewer water in most cases, are liberated from time to time. The gases, however, are, as a rule, of far less importance then the fetid organic matters, the exact nature of which it would be most desirable to examine more thoroughly.

The organic vapor is carbo-ammoniacal; the putrid substance in the sewer water appears, from Odling's observations, to be allied to the compound ammonias; it contains more carbon than methylamine ($NH_2(CH_3)$), and less than ethylamine ($NH_2(C_2H_5)$).

The composition of sewer air will, of course, vary infinitely with the amount of gases disengaged and the degree of ventilation in the sewer. The quantity of oxygen is sometimes in normal amount; it may, however, be diminished in very badly constructed sewers. Parent-Duchâtelet gave an analysis of the air of a choked sewer in Paris, which contained only 13.79 per cent. of oxygen,[5] and no less than 2.99 per cent. of hydrogen sulphide. Excluding this analysis, the greatest impurity in the old Parisian sewers, as determined by Gaultier de Claubry, in 19 analyses[6] in 1829, was 3.4 per cent. of carbon dioxide and 1.25 per cent. of hydrogen sulphide (in different samples of air). The lowest amount of oxygen was 17.4 per cent. Hydrogen sulphide was present in 18 out of 19 cases; the mean of whole 19 cases being .81 per cent. The mean amount of CO_2 in 19 cases was 2.3 per cent. In the present London sewers of good construction the air is much less impure. Dr. Letheby found only .532 per cent. of CO_2, a good deal of ammonia, and only traces of hydrogen sulphide and marsh gas. Dr. Miller's experiments in 1867[7] gave a mean of only 0.106 per cent. of CO_2 in 18 analyses, and .307 per cent. in 6 other instances, the oxygen 20.71 per cent. No hydrogen sulphide was present. Dr. Russell examined the air in the sewers of Paddington in August; the

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[1] Oesterlen, Hygiene, 1857, p. 445.

[2] Ann. d'Hygiene, Oct., 1868, p. 178.

[3] Oesterlen, Handb. der Hyg., 2d edition. p. 445.

[4] Dr. Letheby's experiments, as given in his official Report, in his article in the Encyclopædia Britannica, 8th edition (Sanitary Science), etc., and in a letter to Dr. Adams (given by Dr. Adams in his pamphlet, The Sanitary Aspect of the Sewage Question, 1868, p. 34), are the most complete on this subject.

[5] Hygiène publ., t. i., p. 209, foot-note, and p. 390.

[6] Parent-Duchâtelet's Hyg. publique, t. i., p. 389.

[7] Abstract in Chemical News, March, 1868.

most impure air contained 20.7 oxygen, 78.798 nitrogen, and .51 volume of CO_2 per cent.; there was very little ammonia, and no hydrogen sulphide.

It is evident that, if we take the carbon dioxide and hydrogen sulphide as indices, sewer air has no constant composition. It is sometimes almost as pure as the outside air, while at other times it may be highly impure. But these gases are probably the least important ingredients of sewer air; that organic matters are present is evident from the peculiar fetid smell, and in some cases they are in large amount; 8,000 cubic feet of the air of a house into which sewer air had penetrated destroyed more than 20 times as much potassium permanganate as the same quantity of pure air (Angus Smith). *Fungi* grow rapidly in such air, and meat and milk soon taint when exposed to it. When the sewer air passes through charcoal these substances are absorbed; they may be partly oxidized, as Dr. Miller found some nitric acid in the charcoal, but they also collect in the charcoal and can be recovered (in part at any rate) from it by distillation.[1]

We must also suppose, for facts leave us no other explanation, that the unknown agencies which produce typhoid fever may also be present, and there can be little doubt that cholera[2] may occasionally spread in the same way. The poison of yellow fever (as appears likely from the epidemic in Madrid) may also exist in sewer air. Whether small-pox, scarlet fever, etc., can own a similar channel of distribution is uncertain, although they are no doubt aggravated by it; that dysentery and diarrhœa may also be caused by exhalations proceeding from a foul sewer we cannot doubt, but the precise agency is here also unknown.

The experiments of Professor Frankland[3] show that solid or liquid matter is not likely to be scattered into the air from the sewage itself by any agitation it is likely to undergo, until gas begins to be generated in it. He found that no ordinary agitation (even greater than sewer water is likely to meet with) would scatter particles of lithia solution into the air, but that the bursting of bubbles of carbon dioxide was sufficient to effect it. Hence he argues (with apparent truth) that sewage becomes dangerous in this way only after the setting in of decomposition, so that if we take proper steps to carry away sewage at once the danger becomes reduced to a minimum.

Dr. D. D. Cunningham found large quantities of *bacteria* in the air of the Calcutta sewers.

Air of Churchyards and Vaults.

The decomposition of bodies gives rise to a very large amount of carbon dioxide. It has been calculated that when intramural burial was carried on in London, 2½ millions of cubic feet of CO_2 were disengaged annually from the 52,000 bodies then buried. Ammonia and an offensive putrid vapor are also given off. The air of most cemeteries is richer in CO_2 (.7 to .9 per 1,000, Ramon da Luna), and the organic matter is perceptibly large when tested by potassium permanganate. In vaults, the air contains much CO_2, carbonate or sulphide of ammonium, nitrogen, hydrogen sulphide, and organic matter (Pellieux). Waller Lewes found little SH_2 or CH_4; or cyanogen, or hydrogen phosphide. In his experiments the gas always extinguished flame.

Fungi and germs of *infusoria* abound.

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[1] Miller, Chemical News, March, 1868.

[2] A case in which sewers probably played a part in the dissemination of cholera is given, in Dr. Parkes' Report on the Cholera in Southampton in 1866 to the Medical Officer of the Privy Council.

[3] Proceedings of the Royal Society, 1877.

Air vitiated by certain Trades.

Hydrochloric acid gas, from alkali works.

Sulphur dioxide and sulphuric acid, from copper works—bleaching.

Hydrogen sulphide, from several chemical works, especially of ammonia.

Carbon dioxide, carbonic monoxide, and hydrogen sulphide, from brick fields and cement-works.

Carbon monoxide (in addition to above cases), from iron furnaces, gives rise to from 22 to 25 per cent. (Letheby); from copper furnaces, 15 to 19 per cent. (Letheby).

Organic vapors, from glue refiners, bone-burners, slaughter-houses, knackeries.

Zinc fumes (oxide of zinc), from brass-founders.

Arsenical fumes, from copper-smelting.

Phosphoric fumes, from manufacture of matches.

Carbon disulphide, from some india-rubber works.

Air of Towns.

The air of towns may be vitiated by respiration, combustion, effluvia from the soil, sewers, and trades. The movement of the air tends, however, to continually dilute and remove these impurities, and the heavier particles deposit, so that the air even of manufacturing towns is purer than might have been anticipated. The amount of oxygen in the atmosphere in the purest air near the surface of the earth, being taken as from 20.9 to 20.99 volumes per cent., and the carbon dioxide being from .03 to .045 per cent., with a mean of .04, it would appear, from Angus Smith's observations,[1] that in a crowded part of Manchester, exposed to smoke, the amount of oxygen was from 20.868 to 20.179 per cent.; the average of the street air taken from the laboratory front door was, in Manchester, 20.943; of the closet, a midden behind the laboratory, 20.70. In the London air, in the open spaces, the oxygen amounted to 20.95; in the crowded eastern districts to 20.857.[2] In a foggy frost, in Manchester, when the smoke was not moving much, the amount was 20.91. In Glasgow the average was 20.9092. The variations are, therefore, within narrow limits.

The percentage lessening of oxygen in atmospheric air is partly made up by an increase in the carbon dioxide; but if a town is well built, the increase is trifling; the mean amount of CO_2 for London, in Roscoe's experiments, was only .037 volume per cent.; in Manchester, in usual weather, A. Smith found the amount .0403 per cent.; during fogs, .0679; in the air above the middens, .0774 per cent. It is stated that there is a difference between close and open spaces in towns; thus, in the open spaces (parks) in London, the mean amount in A. Smith's experiments was .0301 per cent.; in Newgate Street (in the City), it was .0413; in Lower Thames Street (City), .0428 per cent. It is not, however, stated whether the observations were made simultaneously.[3] In Glasgow, the average

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[1] Air and Rain, p. 24.

[2] A. Smith, op. cit., p. 30.

[3] In the neighborhood of St. Mary's Hospital, Paddington, I found the mean CO_2 to be 0.056 per cent. in damp still weather, July, 1875; the same locality in dry, hot weather, with a good deal of movement of air, 0.0416 per cent. (August, 1876); in the neighborhood of University College Hospital, damp weather, 0.0736 per cent. in February, 1877.—[F. de C.]

CO_2 was .0502, and in Perth .04136 per cent.[1] In foreign cities the amount is greater, and surpasses the normal limit in air. In Madrid, Ramon da Luna found .0517 as a mean average, and in some cases .08 per cent. ; in Munich, the amount is .05 per cent. These numbers seem, after all, insignificant, but they are not really so, as the aggregate difference, if only .01 per cent., is considerable. In the air of towns which burn coal ther are also, as noted, an excess of acidity (sulphuric and hydrochloric acids), and various suspended matters, which no doubt have injurious effects.[2]

The air of most towns, in addition to ammonia, also contains a nitrogenous substance which, when condensed in pure water, can be made to yield albuminoid ammonia, by Wanklyn's method. In various places in London, A Smith[3] found the amount to average .509 milligramme of albuminoid ammonia in 1 cubic metre. The greatest amount was in a field two miles past Clapham Junction (viz., .27108 milligramme per cubic metre), and the least was in Westminster Abbey Yard (.08555 milligramme). At the shore at Innellan (Firth of Clyde), the amount was .1378 milligramme, and the mean in the streets of Glasgow was .3049 milligramme per cubic metre. In the air of the Underground Railway, in London, the amount was .3734 milligramme.[4] The mean of Mr. Moss's experiments in the open air of Portsmouth was rather less, viz., .0886 milligramme of albuminoid ammonia per cubic metre. This ammonia may be derived from the living beings in the air, or from dead organic matter ; and to bring out the full meaning of such researches, the chemical must be supplemented by a microscopical examination. Ozone is generally absent in town air, but Marié-Davy found at Montsouris an average of .0115 milligramme per cubic metre.[5] This, however, depends very much upon the situation of the observatory and the direction of the prevailing winds. The wind blowing from the open country is richer in ozone than that coming from the town.[6]

These observations prove how important it is to build towns in such a way as to insure good perflation and movement of air everywhere, and to provide open spaces in all the densely crowded parts. The great powers of nature, winds, and the fall of rain, will then, for the most part, keep the atmospheric impurities within limits not injurious to health.

Air of Marshes.

The air of typical marshes contains usually an excess of carbon dioxide, which amounts, perhaps, to .6 or .8 or more per 1,000 volumes. Watery vapor is usually in large quantity. Hydrogen sulphide is present, if the water of the marsh contains sulphates, which, in presence of organic matter, are converted into sulphides, from which SH_2 is derived by the action of vegetable acids. Marsh gas is also often present, and occasionally free hydrogen and ammonia, and, it is said, hydrogen phosphide.[7]

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[1] A. Smith, Air and Rain, p. 50 et seq.

[2] There are also nitrous and nitric acids, due probably to the oxidation of organic matters.

[3] Air and Rain, p. 437. The results are stated in milligrammes per cubic metre, instead of grammes per million cubic metres.

[4] In the garden of St. Mary's Hospital, Paddington, I found .5280 and .5206 mgms. per M. C. (See page 124.) In the back yard of University-College Hospital, .2060 and .3675.—[F. de C.]

[5] Annuaire de l'Observatoire de Montsouris pour l'an 1882.

[6] See Fodor, Die Luft, p. 84, 1881.

[7] Toropoff (of St. Petersburg), considers malaria poison gaseous; after removing water, oxygen, and carbon dioxide, he found marsh air still yielded 84 to 89 per cent. of gaseous matter ; whilst hill air gave only 81.

Organic matter also exists in considerable quantity. Discovered by Vauquelin (1810 and 1811, in the air collected over the Languedoc marshes), by De Lisle, and again by Moscati (1818, in the air of a Lombardy rice-field), and examined more recently by Boussingault (1829, 1839), Gigot (1859), and Becchi (1861), the organic matter seems to have much the same character always. It blackens sulphuric acid when the air is drawn through it; gives a reddish color to nitrate of silver ; has a flocculent appearance, and sometimes a peculiar marshy smell, and, heated with soda-lime, affords evidence of ammonia. The amount in Becchi's experiments was .00027 gramme in a cubic metre of air (= .000118 grain in 1 cubic foot). Ozone, led through a solution of this organic matter, did not destroy it. It is said to destroy quinine. Besides the organic matter, various vegetable matters and animals, floating in the air, are arrested when the air of marshes is drawn through water, or sulphuric acid, and débris of plants, *infusoria*, insects, and even, it is said, small *crustacea* are found ; the ascensional force given by the evaporation of water seems, indeed, to be sufficient to lift comparatively large animals into the air. Dr. M. P. Balestra[1] has described spores and sporangia of a little algoid plant in the air of Rome and its vicinity, and the same plant is found abundantly in the water of the marshes near Rome. Balestra is inclined to attribute marsh fever to this widely diffused "microphyte granule ;" whilst the researches of Klebs and Tommasi-Crudeli have led them to attribute it to a form of *bacillus*, which they have called *B. malariæ*.[2] It has been stated that ozone is deficient in the air over marshes, but the observations of Burdel[3] do not confirm this. He often found as much ozone as in other air. In the air collected from the surface of lakes, containing some aquatic plants, especially *Chara*, there is a large proportion of oxygen, and this air gives, near the surface, the reaction of ozone (Clemens), while at some feet above the reaction is lost. This is usually ascribed to the oxidation of organic matter, which rises simultaneously from the water.

Air in the Holds of Ships.

The air in the holds of ships is compounded of exhalations from the wood, bilge-water, and cargo. Owing to the comparative immobility of the air, it often becomes extremely foul. The composition is not known, but the smell of hydrogen sulphide is very perceptible, and white paint is blackened. In some cases, when the water-tanks are filled by condensed water from the engines, which is not well cooled, the hold may become extremely hot (100° to 120° Fahr.), and decomposition be much increased.

Air of Mines.

In the metalliferous mines the air, according to Angus Smith,[4] is poor in oxygen (20.5 per cent. sometimes), and very rich in carbon dioxide (7.85 per 1,000 volumes on a mean of many experiments). It also contains organic matter, giving, when burnt, the smell of burnt feathers, in uncertain amount. These impurities arise from respiration, combustion from lights, and from gunpowder blasting.' This latter process adds to the air, in addition to carbon dioxide, carbon monoxide, hydrogen and hydrogen sul-

[1] Comptes Rendus, 1870, No. 3, July, p. 235.
[2] Studii sulla Natura della Malaria, Roma, 1879.
[3] Recherches sur les fièvres paludéennes, 1858.
[4] Report on Mines, Blue Book, 1864.

phide, various solid particles, consisting of suspended salts, which may amount to as much as 3 grains in each cubic foot of air. These suspended substances are principally potassium sulphate, carbonate, hyposulphite, sulphide, sulphocyanide, and nitrate, carbon, sulphur, and ammonium sesquicarbonate.

Much of this may hereafter be avoided by the new process of getting coal, by means of compressed quicklime, which is slacked in holes drilled in the coal.

SECTION II.

DISEASES PRODUCED BY IMPURITIES IN AIR.

Sub-Section I.—Suspended Solid Matters.

1. *Dead Substances.*—The effect which is produced on the respiratory organs by substances inhaled into the lungs has long been known. Ramazzini and several other writers in the last century, and Thackrah fifty years ago in this country, directed special attention to this point, and since that time a great amount of evidence has accumulated,[1] which shows that the effect of dust of different kinds in the air is a far more potent cause of respiratory diseases than usually admitted. Affections of the digestive organs are also caused, but in a much slighter degree. The respiratory affections are frequently recurring catarrhs (either dry or with expectoration) and bronchitis, with subsequent emphysema, although this sequence appears from the figures given by Hirt to be not quite so frequent as was supposed, perhaps from the cough not being violent. Acute pneumonia, and especially chronic non-tubercular phthisis, are also produced. The suspended matters in the air which may produce these affections may be mineral, vegetable, or animal; but it would seem that the severity of the effects is chiefly dependent on the amount of dust, and on the physical conditions as to angularity, roughness, or smoothness of the particles, and not on the nature of the substance, except in some special cases. A large number of the unhealthy trades are chiefly so from this cause; this is the case, in fact, with miners of all kinds.[2] Mr. Simon[3] states, that with one exception, the 300,000 miners in England break down as a class prematurely from bronchitis and pneumonia caused by the atmosphere in which they live. The exception is most important.

The colliers of Durham and Northumberland, where the mines are well ventilated, do not appear to suffer from an excess of pulmonary disease, or do so in a slight degree only. In different mines, also, the amount of

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[1] The whole subject has been lately very carefully investigated by Hirt. Die Krankheiten der Arbeiter, Erste Theil, Staubinhalations-Krankheiten, von Dr. L. Hirt. 1871. See also Eulenberg, Gewerbe Hygiene, 1876.

[2] Thackrah enumerates the following in his work on the Effect of Arts, Trades, and Professions on Health, 1832, p. 63:—The workmen who were affected injuriously by the dust of their trades 50 years ago, and the same list will almost do for the present day: Cornmillers, maltsters, teamen, coffee-roasters, snuff-makers, papermakers, flock-dressers, feather-dressers, shoddy-grinders, weavers of coverlets, weavers of harding, dressers of hair, hatters employed in the bowing department, dressers of colored leather, workers in flax, dressers of hemp, some workers in wood, wire-grinders, masons, colliers, iron miners, lead miners, grinders of metals, file-cutters, machine-makers, makers of firearms, button-makers. Hirt (op. cit.) also gives an extended table.

[3] Fourth Report of the Medical Officer of the Privy Council, 1862, p. 15 et seq. See also Arlidge, in B. and F. Med. Chir. Rev., July, 1864, for the effects of the pottery trade.

pulmonary disease is different, apparently according to the amount of ventilation.

The following table is given by the Registrar-General:—[1]

Average Annual Deaths per 1,000 *from Pulmonary Disease during the Years* 1860–62 *inclusive.*

Ages.	Metal Miners in Cornwall.	Metal Miners in Yorkshire.	Metal Miners in Wales.	Males, exclusive of Miners, in Yorkshire.
Between 15 and 25 years,	3.77	3.40	3.02	3.97
" 25 " 35 "	4.15	6.40	4.19	5.15
" 35 " 45 "	7.89	11.76	10.62	3.52
" 45 " 55 "	19.75	23.18	14.71	5.21
" 55 " 65 "	43.29	41.47	35.31	7.22
" 65 " 75 "	45.04	53.69	48.31	17.44

The enormous increase of lung diseases among the miners after the age of 35, is seen at a glance.

In the pottery trade all classes of workmen are exposed to dust, especially, however, the flat-pressers. So common is emphysema that it is called "the potters' asthma."

So also among the china scourers; the light flint dust disengaged in great quantities is a "terrible irritant." Dr. Greenhow states that *all* sooner or later become "asthmatical."

The grinders of steel, especially of the finer tools, are perhaps the most fatally attacked of all, though of late years the evil has been somewhat lessened by the introduction of wet-grinding in some cases, by the use of ventilated wheel-boxes, and by covering the work with linen covers when practicable. The wearing of masks and coverings for the mouth appears to be inconvenient, otherwise there is no doubt that a great amount of the dust might be stopped by very simple contrivances.[2]

Button-makers, especially the makers of pearl buttons, also suffer from chronic bronchitis, which is often attended with hæmoptysis. So also pin-pointers, some electro-plate workmen, and many other trades of the like kind, are more or less similarly affected.

In some of the textile manufactures much harm is done in the same way. In the carding rooms of cotton, and wool, and silk spinners, there is a great amount of dust and flue, and the daily grinding of the engines disengages also fine particles of steel. Since the cotton famine, a size composed in part of china clay (35.35 grains of clay in 100 of sizing on an average), has been much used in cotton mills, and the dust arising seems certainly to be producing injurious effects on the lungs of the weaver.[3]

In flax factories a very irritating dust is produced in the process of hackling, carding, line-preparing, and tow-spinning. Of 107 operatives, whose cases were taken indiscriminately by Dr. Greenhow, no less than 79 were suffering from bronchial irritation, and in 19 of these there had been

[1] Report of the Commissioners on Mines, Blue-book, 1864.

[2] See for further particulars and much interesting information Dr. Hall's paper read at the Social Science Congress in 1865.

[3] G. Buchanan's Report on certain Sizing Processes used in the Cotton Manufacture at Todmorden. Ordered to be printed by the House of Commons. May, 1872.

hæmoptysis. Among 27 hacklers, 23 were diseased.[1] In shoddy factories, also, the same thing occurs. These evils appear to be entirely and easily preventable. In some kinds of glass-making, also, the workmen suffer from floating particles of sand and felspar, and sometimes potash or soda-salts.

The makers of grinding-stones suffer in the same way; and children working in the making of sand-paper are seriously affected, sometimes in a very short time, by the inhalation of fine particles of sand into the lungs.

In making Portland cement, the burnt masses of cement are ground down and then the powder is shovelled into sacks; the workmen doing this cough a great deal, and often expectorate little masses of cement. Some of them have stated that if they had to do the same work every day, it would be impossible to continue it on account of the lung affection.

The makers of matches, who are exposed to the fumes of phosphorus, suffer from necrosis of the jaw, if there happens to be any exposed part on which the fumes can act. This, however, is now obviated by the use of amorphous or red phosphorus, which is harmless.

In making bichromate of potash, the heat and vapor employed carry up fine particles, which lodge in the nose and cause great irritation, and finally ulceration, and destruction of both mucous membrane and bone. Those who take snuff escape this. The mouth is not affected, as the fluids dissolve and get rid of the salt. The skin is also irritated if the salt is rubbed on it, and fistulous sores are apt to be produced. No effect is noticed to be produced on the lungs.[2] Washing the skin with subacetate of lead is the best treatment.

In the process of sulphuring vines the eyes often suffer, and sometimes (especially when lime is used with the sulphur) decided bronchitis is produced.

In some trades, or under special circumstances, the fumes of metals, or particles of metallic compounds, pass into the air. Brassfounders suffer from bronchitis and asthma, as in other trades in which dust is inhaled; but in addition they also suffer from the disease described by Thackrah as "brass ague," and by Dr. Greenhow as "brassfounders' ague." It appears to be produced by the inhalation of fumes of zinc oxide;[3] the symptoms are tightness and oppression of the chest, with indefinite nervous sensations, followed by shivering, an indistinct hot stage, and profuse sweating. These attacks are not periodical.

Coppersmiths are affected somewhat in the same way, by the fumes arising from the partly volatilized metal, or from the spelter (solder).

Tinplate workers also suffer occasionally from the fumes of the soldering.

Plumbers inhale the volatilized oxide of lead which rises during the process of casting. Nausea and tightness of the chest are the first symptoms, and then colic and palsy.

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[1] Mr. Simon's Fourth Report, p. 19.

[2] Chevallier, Ann. d'Hygiène, July, 1863, p. 83.

[3] Some doubt has been expressed as to those symptoms being produced by *pure* zinc fumes; see Hirt (op. cit.), who says that men employed in making zinc houses, where they inhale *pure* zinc fumes without copper, never suffer from brassfounder's ague. On the other hand, he describes very graphically the effect of the metallic fumes (copper ?) on himself. The workmen think that drinking large quantities of milk lessens the severity of the attacks.

Manufacturers of white lead inhale the dust chiefly from the white beds and the packing.

House painters also inhale the dust of white lead to a certain extent, though in these, as in former cases, much lead is swallowed from want of cleanliness of the hands in taking food.

Workers in tobacco factories suffer in some cases, and there are persons who can never get accustomed to the work ; yet with proper care and ventilation it appears [1] that no bad effects ordinarily result.

Workers in mercury, silverers of mirrors, and water gilders (men who coat silver with an amalgam of mercury and gold), are subject to mercurialismus. But electricity has rendered gilding with the aid of mercury to some extent obsolete ; and the making of mirrors with nitrate of silver may perhaps ultimately abolish all the horrors of mercurial labor.

Workmen who use arsenical compounds, either in the making of wall papers or of artificial flowers, etc., suffer from slight symptoms of arsenical poisoning, and many persons who have inhaled the dust of rooms papered with arsenical papers have suffered from both local and constitutional effects,—the local being smarting of the gums, eyes, nose, œdema of the eyelids, and little ulcers on the exposed parts of the body ; the constitutional being weakness, fainting, asthma, anorexia, thirst, diarrhœa, and sometimes even severe nervous symptoms.[2] Arsenic has been detected in the urine of such persons.

A. Manouvriez[3] gives an account of the diseases among workmen in France employed in making patent fuel, a mixture of coal-dust and pitch. He says they suffer from melanodermy, cutaneous eruptions, and epithelial cancers, affections of the eyes, ears, and nose ; bronchitis with pulmonary pseudo-melanosis ; and gastro-entero-hepatic disorders. Hirt also mentions some of the diseases produced among workmen by the various tar-products.

2. *Living Substances, as Infusoria, Fungi, Algæ, or their germs, or Pollen or Effluvia of Flowers.*—That summer catarrh or hay fever is produced in many persons by the pollen from grasses (especially *Anthoxanthum odoratum*), trees or flowers, is now generally admitted. The researches of Dr. Blackley,[4] of Manchester (himself a sufferer), have placed the matter beyond a doubt. In his case, at least, it was pollen that produced the disease, and not the effluvia merely. Coumarin had no effect. Grass-pollen (which constitutes 95 per cent. of the pollen floating in the atmosphere) and the pollen from pine-trees were the most powerful in effect. Curiously enough, the pollen of poisonous plants, such as the Solanaceæ, was often comparatively innocuous. It is also known that the spores of certain *fungi* in falling on a proper soil may cause disease of the skin in men, and that *tinea* and *favus* are thus sometimes spread seems certain. There is a growing belief in the connection of the specific diseases with low vegetable forms. Dr. Salisbury, of Ohio, attempted to trace ague to a *Palmella ;* others have ascribed it to the *Oscillarineæ* generally ; Dr. Balestra believes that a special *alga* is the efficient cause, and Klebs and Tommasi-Crudeli attribute it to the *Bacillus malariæ*.

Dr. Salisbury has also affirmed that the prevalence of measles in the Federal army arose from *fungi* from mouldy straw. He inoculated himself, his wife, and forty other persons with the *fungi*, and produced a dis-

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[1] Hirt, op. cit., pp. 162, 163.

[2] See paper by Mr. Jabez Hogg, Sanitary Record, April 25, 1879.

[3] Annales d'Hygiène, March, 1876.

[4] Op. cit.

ease like measles in from twenty-four to ninety-six hours. It is stated also that this disease was protective against measles. Dr. Woodward (United States Army) has repeated Dr. Salisbury's experiments, but does not confirm them.[1]

Professor Hallier, of Jena, has to some extent adopted the view that *fungi* give rise to some of the specific diseases, and that the spores float in the air, and are thus communicated, but the proofs are not satisfactory.[2]

Dr. D. D. Cunningham says that he was unable to connect any disease, in Calcutta, with the occurrence of *bacteria* or other bodies in the air, either as regards variation in kind or in quantity.

Blackley found that *Chætonium elatum* (bristle mould) produced nausea, fainting, and giddiness, and the spores of *penicillium* (inhaled) brought on hoarseness, going on to complete aphonia; the condition lasted two days, and ended in a sharpish attack of catarrh.

Pettenkofer, Von Nägeli, Fodor, and many others distinctly attribute specific diseases to *bacteria* of certain kinds. The connection of the woolsorters' disease with the existence of *bacillus* in the body of the patient has been established, and this is in all probability inhaled from the atmosphere in which the men work.

Koch has recently demonstrated the presence of a *bacillus* in cases of phthisis, and has apparently succeeded in cultivating it, and propagating the disease by that means.

3. *The Contagia.*—Under this head it will be convenient to include the unknown causes of the specific diseases. That these in some cases (scarlet fever, small-pox, measles, typhus, enteric fever, plague, pertussis, yellow fever, influenza, etc.) reach the person through the medium of air (as well as in some cases through water or food) cannot be doubted. Some of these contagia have in some way a power of growth and multiplication in the body of a susceptible animal, but whether they can find nourishment, and thus grow in the air, is yet doubtful. It seems clear, however, that they can retain the powers of growth for some time, as the small-pox and scarlet fever poisons may infect the air of a room for weeks, and cattle plague and enteric fever poisons will last for months,[3] and in this they resemble *Protococci* and other low forms of life, which can be dried for years, and yet retain vitality.

The exact condition of the agency is unknown; whether it is in the form of impalpable particles, or moist or dried epithelium and pus-cells, is a point for future inquiry; and whether it is always contained in the substances discharged or thrown off from the body (as is certainly the case in small-pox), or is produced by putrefactive changes in those discharges, as is supposed to be the case in cholera and dysentery, is also a matter of doubt. Bakewell[4] collected dust deposited at a height of 7 or 8 feet in small-pox wards, which contained the minute scabs with the epidermic scales and variolous corpuscles which are thrown off from the skin

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[1] Camp Diseases in the U. S. Army, p. 278. The fungus is a *Penicillium.*

[2] Many papers on this subject by Hallier and others are contained in Hallier's Zeitschrift für Parasitenkunde.

[3] The long retention of power by the enteric fever poison is shown by a case related by Dr. Becher (Army Med. Department Report, vol. 10, p. 237). The typhoid poison appears to have adhered to the walls and ceiling, and to have retained its power to excite disease in another person for a month; it was not destroyed by the heat of a very hot Indian station (Gwalior) in February.

[4] Med. Times and Gazette, December 7, 1872.

in small-pox. Some modern expositors of the old doctrine of fomites would consider these organic matters to be inconceivably minute particles of living, or to use Dr. Beale's phrase, bioplastic matter, which is capable, he believes, of wonderfully rapid growth under proper conditions.[1] But it is also probable that some, if not all, the disease poisons are really living organisms, a view very widely received now both in this country and elsewhere.

The specific poisons manifestly differ in the ease with which they are oxidized and destroyed. The poison of typhus exanthematicus is very readily got rid of by free ventilation, by means of which it must be at once diluted and oxidized, so that a few feet give, under such circumstances, sufficient protection. This is the case also with the poison of oriental plague, while, on the other hand, the poisons of small-pox and scarlet fever will spread in spite of very free ventilation, and retain their power of causing the same disease for a long time. In the case of malaria, the process of oxidation must be slow, since the poison can certainly be carried for many hundred yards ; even sometimes for more than a mile in an upward direction (up a ravine, for instance), or horizontally, if it does not pass over the surface of water. The poison of cholera also, some have supposed, can be blown by the winds for some distance ; but the most recent observations on its mode of spread lead to the conclusion that the portability of the poison in this way has been greatly overrated. The poison of diphtheria appears also to be transported some distance by wind.

But the specific poisons are not the only suspended substances which thus float through the atmosphere.

There can be no doubt that while purulent and granular ophthalmia most frequently spread by direct transference of the pus or epithelium-cells, by means of towels, etc., and that erysipelas and hospital gangrene, in surgical wards, are often carried in a similar way, by dirty sponges and dressings, another mode of transference is by the passage into the atmosphere of disintegrating pus-cells and putrefying organic particles, and hence the great effect of free ventilation in military ophthalmia (Stromeyer), and in erysipelas[2] and hospital gangrene. In both these diseases, great evaporation from the walls or floors seems in some way to aid the diffusion, either by giving a great degree of humidity, or in some other way. The practice of frequently washing the floors of hospitals is well known to increase the chance of erysipelas, and this might be explained, as Von Nägeli suggests, by the moisture and subsequent drying helping the development and subsequent dissemination of minute organisms.

SUB-SECTION II.—GASEOUS MATTERS.

(*a*) *Carbon Dioxide.*—The normal quantity of CO_2 being .4 volume per 1,000, it produces fatal results when the amount reaches from 50 to 100 per 1,000 volumes ; and at an amount much below this, 15 to 20 per 1,000, it produces, in some persons at any rate, severe headache. Other persons can inhale, for a brief period, considerable quantities of carbon dioxide without injury ;[3] and animals can be kept for a long time in an atmosphere highly charged with it, provided the amount of oxygen be also increased. In the air of respiration, headache and vertigo are produced when the

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[1] See chapter on DISINFECTION for a fuller notice of these points.

[2] See my Reports on St. Mary's Hospital, loc. cit.—[F. de C.]

[3] It is stated that Sir R. Christison employed air containing 20 per cent. of carbon dioxide as an anæsthetic. (Taylor's Jurisprudence, 1865, p. 713.)

amount of CO_2 is not more than 1.5 to 3 volumes per 1,000 ; but then organic matters, and possibly other gases, are present in the air, and the amount of oxygen is also lessened. Well-sinkers, when not actually disabled from continuing their work by CO_2, are often affected by headache, sickness, and loss of appetite ; but the amount of CO_2 has never been determined.

The effect of constantly breathing an atmosphere containing an excess of CO_2 (up to 1 or 1.5 per 1,000 volumes) is not yet perfectly known. Dr. Angus Smith [1] has attempted to determine its effect of, *per se*, the influence of the organic matter of respiration being eliminated. He found that 30 volumes per 1,000 caused great feebleness of the circulation, with, usually, slowness of the heart's action ; the respirations were, on the contrary, quickened, but were sometimes gasping. These effects lessened when the amount was smaller, but were perceptible when the amount was as low as 1 volume per 1,000—an amount often exceeded in dwelling-houses. At the same time, this is not the case always, for in the air of a soda-water manufactory, when CO_2 was 2 per 1,000, Smith found no discomfort to be produced. The effects noticed by Smith have not been observed in experiments on animals, by Demarquay, W. Müller, and Eulenberg,[2] nor in other cases in men, as in the bath at Oeynhausen, where no effect is produced by the air of the room in which the bathers remain for 30 to 60 minutes, although it contains a large percentage. It has been supposed that lung diseases, especially phthisis, are produced by it ; but as this opinion has been drawn merely from the effects of the air of respiration, which is otherwise vitiated, it cannot be considered to stand on any sure basis. Hirt finds no symptoms of chronic poisoning by CO_2, even in trades where acute poisoning occasionally occurs.[3]

The presence of a very large amount of CO_2 in the air may lessen its elimination from the lungs, and thus retain the gas in the blood, and in time possibly produce serious alterations in nutrition.

(*b*) *Carbon Monoxide*.—Of the immense effect of carbon monoxide, there is no doubt. Less than one-half per cent. has produced poisonous symptoms, and more than one per cent. is rapidly fatal to animals. It appears from Bernard's and from Lothär Meyer's observations,[4] that the gas, volume for volume, completely replaces the oxygen in the blood, and cannot be again displaced by oxygen, so that the person dies asphyxiated ; but Pokrowsky has shown [5] that it may gradually be converted into carbon dioxide, and be got rid of. It seems, in fact, as Hoppe-Seyler conjectured, to completely paralyze, so to speak, the red particles, so that they cannot any longer be the carriers of oxygen. The observations of Dr. Kleber [6] show that, in addition to loss of consciousness and destruction of reflex action, it causes complete atony of the vessels, diminution of the vascular pressure, and slowness of circulation, and finally paralysis of the heart. A very rapid parenchymatous degeneration takes place in the heart and muscles generally, and in the liver, spleen, and kidneys. Hirt [7] says that at high temperatures (25°–32° Cent. = 77°–90° Fahr.) it produces convulsions, but not at low temperatures (8°–12° Cent. = 46°–53° Fahr.).

(*c*) *Hydrogen Sulphide*.—The evidence with regard to this gas is contra-

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[1] Air and Rain, p 209 et seq. [2] Quoted by Roth and Lex, op. cit., p. 176.
[3] Die Krankheiten der Arbeiter, Erste Abtheilung, 2ter Theil, 1873.
[4] De Sanguine Oxydo carbonico Infecto, 1858. Reviewed in Virchow's Archiv, Band xv., 309. See also Letheby, Chemical News, April, 1862.
[5] Virchow's Archiv, Band xxx., p. 525 (1864).
[6] Ibid., Band xxxii., p. 450 (1865). [7] Op. cit.

dictory. While dogs and horses are affected by comparatively small quantities (1.25 and 4 volumes per 1,000 volumes of air), and suffer from purging and rapid prostration, men can breathe a larger quantity. Parent-Duchâtelet inhaled an atmosphere containing 29 volumes per 1,000 for some short time.[1]

When inhaled in smaller quantities, and more continuously, it has appeared in some cases harmless, in others hurtful. Thackrah, in his inquiries, could trace no bad effects. It is said that in the Bonnington chemical-works, where the ammoniacal liquor from the Edinburgh gas-works is converted into sulphate and chloride of ammonium, the workmen are exposed to the fumes of ammonium and hydrogen sulphides to such an extent that coins are blackened ; yet no special malady is known to result. The same observations have been made at the Britannia metal-works, where a superficial deposit of sulphide is decomposed with acids.

Hirt[2] has no doubt of the occurrence of chronic poison among men who work among large quantities of the gas. The symptoms are chiefly weakness, depression, perfect anorexia, slow pulse, furred tongue, mucous membrane of the mouth pale, as is also the face. Sometimes there is furunculoid eruption in different parts of the body. In some cases there are vertigo, headache, nausea, diarrhœa, emaciation, and head symptoms, "like a case of very slow-running typhus." He notices differences of susceptibility, which is also sometimes increased with custom.

So large a quantity of SH_2 is given out from some of the salt marshes at Singapore, that slips of paper moistened in acetate of lead are blackened in the open air ; yet not only is no bad effect found to ensue, but Dr. Little has even conjectured (on very disputable grounds, however), that the SH_2 may neutralize the marsh miasma.

On the other hand, some of the worst marshes in Italy are those in which SH_2 exists in large quantity in the air ; and, in direct opposition to Little, it has been supposed that the highly poisonous action of the marsh gas is partly owing to the SH_2. Again, in the making of the Thames Tunnel, the men were exposed to SH_2, which was formed from the decomposition of iron pyrites ; after a time they became feeble, lost their appetites, and finally passed into a state of great prostration and anæmia. Nor, so far as is known, was there anything to account for this except the presence of SH_2.[3]

Dr. Josephson and Rawitz[4] have also investigated in mines effects produced apparently by SH_2 ; two forms of disease are produced—pure narcotic, and convulsive and tetanic symptoms. In the first case, the men became pale, the extremities got cold. There was headache, vertigo, a small weak pulse, sweating, and great loss of strength. On this, spasms and tremblings sometimes followed, and even tetanus. These symptoms were acute, and not, as in the Thames Tunnel case, chronic. When these attacks occurred, the temperature was high and the air stagnant.

The observations of Clemens, also, on the development of boils from the passage of SH_2 into the drinking water from the air, if not convincing, cannot be overlooked.

The symptoms produced by ammonium sulphide in dogs are said, by

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[1] On dogs, Herbert Barker found a larger quantity necessary than that stated above; viz., 4.29 per 1,000 is rapidly fatal, 2.06 per 1,000 may be fatal, but .5 per 1,000 may produce serious symptoms.

[2] Op. cit.

[3] Taylor's Med. Jurisp., 1865, p. 727.

[4] Schmidt's Jahr., Band cx., p. 334, and Band cxvii., p. 85.

Herbert Barker,[1] to differ from those of SH_2. There is vomiting without purging, quickened pulse, and heat of skin, followed by coldness and rapid sinking. When hydrogen and ammonium sulphides, dissolved in water, are injected into the blood,[2] they, and especially SH_2, produce the same symptoms as the injection of non-corpuscular putrid fluids, viz., profuse diarrhœal evacuations, with sometimes marked choleraic symptoms and decided lowering of the temperature of the body, congestions of the lungs, liver, spleen, and kidneys, irritation of the spine, and opisthotonos. But, in this case, a much larger quantity will be introduced than by inhalation through the lungs.

(*d*) *Carburetted Hydrogen.*—A large quantity of carburetted hydrogen can be breathed for a short time ; as much, perhaps, as 200 to 300 volumes per 1,000. Above this amount it produces symptoms of poisoning, headache, vomiting, convulsions, stertor, dilated pupil, etc.

Breathed in small quantities, as it constantly is by some miners, it has not been shown to produce any bad effects ; but there, as in so many other cases, it is to be wished that a more careful examination of the point were made. Without producing any marked disease, it may yet act injuriously on the health. Hirt says that cases of chronic poisoning are not uncommon.

(*e*) *Ammoniacal Vapors.*—An irritating effect on the conjunctiva seems to be the most marked effect of the presence of these vapors. There is no evidence showing any other effect on the health.[3]

(*f*) *Sulphur Dioxide.*—The bleachers in cotton and worsted manufactories, and storers of woollen articles, are exposed to this gas, the amount of which in the atmosphere is, however, unknown. The men suffer from bronchitis, and are frequently sallow and anæmic.[4]

When SO_2 is evolved in the open air, and therefore at once largely diluted, as in copper smelting, it does not appear to produce any bad effects in men, though from being washed down with rain, it affects herbage, and, through the herbage, cattle, causing affections of the bones, falling off of the hair, and emaciation.

(*g*) *Hydrochloric Acid Vapors* in large quantities are very irritating to the lungs ; when poured out into the air, as was formerly the case in the alkali manufactures, they are so diluted as apparently to produce no effect on men, but they completely destroy vegetation. In some processes for making steel, hydrochloric, sulphurous and nitrous acids, and chlorine are all given out, and cause bronchitis, pneumonia, and destruction of lung tissue, as well as eye diseases.[5]

(*h*) *Carbon Disulphide.*—In certain processes in the manufacture of vulcanized india-rubber a noxious gas is given off, supposed to be the vapor of carbon disulphide. It produces headache, giddiness, pains in the limbs, formication, sleeplessness, nervous depression, and complete loss of appetite. Sometimes there is deafness, dyspnœa, cough, febrile attacks, and even amaurosis and paraplegia (Delpech). The effects seem due to a direct anæsthetic effect on the nervous tissue.

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[1] On Malaria and Miasmata, p. 212.

[2] Weber, Syd. Soc. Year-Book for 1874, p. 227.

[3] See Schloesing, Comptes Rendus, 1875, vols. i. and ii.

[4] On the other hand, persons living in volcanic countries have sometimes a notion that the fumes of SO_2 are good for the health ; I have been told so by people in the neighborhood of Vesuvius.—[F. de C.]

[5] Jordan, Canstatt's Jahresb. for 1863, Band vii., p. 76.

Sub-Section III.—Effect of Air Impure from several Substances always Coexisting.

The examination of the effects of individual gases, however important, can never teach us the results which may be produced by breathing air rendered foul by a mixture of impurities. The composite effect may possibly be very different from what would have been anticipated from a knowledge of the action of the isolated substances.

(a) *Air rendered Impure by Respiration.*—The effect of the fetid air containing organic matter, excess of water and CO_2, produced by respiration is very marked upon many people ; heaviness, headache, inertness, and in some cases nausea, are produced. From experiments on animals in which the carbon dioxide and watery vapor were removed, and organic matter alone left, Gavarret and Hammond have found that the organic matter is highly poisonous. Hammond found that a mouse died in forty-five minutes, and cases have been known in which the inhalation of such an atmosphere for three or four hours produced in men decided febrile symptoms (increased temperature, quickened pulse, furred tongue, loss of appetite, and thirst), for even twenty-four or forty-eight hours subsequently (Parkes).

When the air is rendered still more impure than this, it is rapidly fatal, as in the cases of the Black Hole at Calcutta ; of the prison in which 300 Austrian prisoners were put after the battle of Austerlitz (when 260 died very rapidly) ; and of the steamer Londonderry. The poisonous agencies are probably the organic matter and the deficient oxygen, as the symptoms are not those of pure asphyxia. If the persons survive, a febrile condition is left behind, which lasts three or four days, or there are other evidences of affected nutrition, such as boils, etc.

When air more moderately vitiated by respiration is breathed for a longer period, and more continuously, its effects become complicated with those of other conditions. Usually a person who is compelled to breathe such an atmosphere is at the same time sedentary, and, perhaps, remains in a constrained position for several hours, or possibly is also under-fed or intemperate. But allowing the fullest effect to all other agencies, there is no doubt that the breathing the vitiated atmosphere of respiration has a most injurious effect on the health.[1] Persons soon become pale, and partially lose their appetite, and after a time decline in muscular strength and spirits.[2] The aëration and nutrition of the blood seem to be interfered with, and the general tone of the system falls below par. Of special diseases it appears pretty clear that pulmonary affections are more common.

Such persons do certainly appear to furnish a most undue percentage of phthisical cases ; that is, of destructive lung-tissue disease of some kind. The production of phthisis from impure air (aided most potently, as it often is, by coincident conditions of want of exercise, want of good food, and excessive work) is no new doctrine.[3] Baudelocque long ago asserted that

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[1] See, among a number of other instances, Guy's Evidence before the Health of Towns Commission, vol. i., p. 89 et seq. ; and S. Smith, ibid., p. 37 et seq.

[2] See Wilson's observations on Prisoners, already cited, page 122.

[3] The following statistics (Ransom, Sanitary Record, vol. vi.) are instructive : Death-rate from diseases of the respiratory organs for all England, 3.54 (1865–76 ; for Salford, 5.12 ; for registration district of Manchester, 6.10 ; for township of Manchester in 1874, 7.7 ; for Westmoreland (one of the healthiest counties), 2.27 ; for North Wales, 2.51. For diagrams showing the effects of aggregation of population on the ratio of respiratory diseases, see my Lectures on State Medicine, table v., p. 48.—[F. de C.]

impure air is the great cause of scrofula (phthisis), and that hereditary predisposition, syphilis, uncleanness, want of clothing, bad food, cold and humid air, are by themselves non-effective. Carmichael, in his work on scrofula (1810), gives some most striking instances, where impure air, bad diet, and deficient exercise concurred together to produce a most formidable mortality from phthisis. In one instance, in the Dublin House of Industry, where scrofula was formerly so common as to be thought contagious, there were in one ward 60 feet long and 18 feet broad (height not given), 38 beds, each containing four children ; the atmosphere was so bad that in the morning the air of the ward was unendurable. In some of the schools examined by Carmichael, the diet was excellent, and the only causes for the excessive phthisis were the foul air and the want of exercise. This was the case also in the house and school examined by Neil Arnott in 1832. Lepelletier [1] also records some good evidence. Professor Alison, of Edinburgh, and Sir James Clark, in his invaluable work, lay great stress on it. Neil Arnott, Toynbee, Guy, and others, brought forward some striking examples before the Health of Towns Commission.[2] Dr. Henry MacCormac has insisted with great cogency on this mode of origin of phthisis ; and Dr. Greenhow [3] also enumerates this cause as occupying a prominent place.

In prisons, the great mortality which formerly occurred from phthisis, as for example at Millbank (Baly), seemed to be owing to bad air, conjoined with inferior diet and moral depression.

Two Austrian prisons, in which the diet and mode of life were, it is believed, essentially the same, offer the following contrast :—

In the prison of Leopoldstadt, at Vienna, which was very badly ventilated, there died in the years 1834–1847, 378 prisoners out of 4,280, or 86 per 1,000, and of these no less than 220, or 51.4 per 1,000, died from phthisis ; there were no less than 42 cases of acute miliary tuberculosis.

In the well-ventilated House of Correction in the same city, there were in five years (1850–1854) 3,037 prisoners, of whom 43 died, or 14 per 1,000, and of these 24, or 7.9 per 1,000, died of phthisis. The comparative length of sentences is not given, but no correction on this ground, if needed, could account for this discrepancy. The great prevalence of phthisis in some of the Indian jails appears to have been owing to the same cause, combined with insufficient diet.

The now well-known fact of the great prevalence of phthisis in most of the European armies (French, Prussian, Russian, Belgian, and English) can scarcely be accounted for in any other way than by supposing the vitiated atmosphere of the barrack-room to have been chiefly in fault. This is the conclusion to which the Sanitary Commissioners for the army came in their celebrated report. And if we must also attribute some influence to the pressure of ill-made accoutrements, and to the great prevalence of syphilis, still it can hardly be doubted that the chief cause of phthisis among soldiers has to be sought somewhere else, when we see that, with very different duties, a variable amount of syphilis, and altered diet, a great amount of phthisis, has prevailed in the most varied stations of the army, and in the most beautiful climates ; in Gibraltar, Malta, Ionia, Jamaica, Trinidad, Bermuda, etc. (see history of these stations), in all which places the only common condition was the vitiated atmosphere which

[1] Traité Complet de la Maladie Scrophuleuse.
[2] First Report, 1844, vol. i., pp. 52, 60, 69, 79, etc.
[3] Report on the Health of the People of England.

our barrack system everywhere produced. And, as if to clench the argument, there has been of late years a most decided decline in phthisical cases in these stations, while the only circumstance which has notably changed in the time has been the condition of the air. So also the extraordinary amount of consumption which has prevailed among the men of the Royal and Merchant Navies, and which, in some men-of-war, has amounted to a veritable epidemic, is in all probability attributable to the faulty ventilation.[1]

The deaths from phthisis in the Royal Navy averaged (3 years) 2.6 per 1,000 of strength, and the invaliding 3.9 per 1,000. The amount of consumption and of all lung diseases was remarkably different in the different ships. These inferences received the strongest corroboration from the outbreak of a lung disease leading to the destruction of lung tissue in several of the ships on the Mediterranean station in 1860. Dr. Bryson traced this clearly to contamination of the air, and noticed that in several cases the disease appeared to be propagated from person to person.[2] It may be inferred that pus-cells were largely thrown off during coughing, and, floating through the air, were received into the lungs of other persons.

The production of phthisis in animals confirms this view. The case of the monkeys in the zoological gardens, narrated by Dr. Arnott, is a striking instance. Cows in close stables frequently die from phthisis, or at any rate from a destructive lung disease (not apparently pleuro-pneumonia); while horses, who in the worst stables have more free air, and get a greater amount of exercise, are little subject to phthisis. But not only phthisis may reasonably be considered to have one of its modes of origin in the breathing an atmosphere contaminated by respiration, but other lung diseases, bronchitis and pneumonia, appear also to be more common in such circumstances. Both among seamen and civilians working in confined close rooms, who are otherwise so differently circumstanced, we find an excess of the acute lung affections. The only circumstance which is common to the two classes is the impure atmosphere. (Compare especially Gavin Milroy and Greenhow.) The favorite belief that these diseases are caused by transitions of temperature and exposure to weather, has been carried too far.

In the South Afghanistan field force the artillery wintered at Kandahar (1880–81) in tents, and remained free from pneumonia, whilst the disease was prevalent among the infantry who were overcrowded in barracks. The 63d, which was more crowded than the other corps, suffered most, having 30 cases in hospital at one time ; one company, however, quartered in large airy rooms near the residence of the General commanding, had no case. On the 25th of March a part of the regiment was turned out into tents and the remainder were distributed in barracks, so that each man had a minimum of 600 cubic feet of space ; from that time no more pneumonia occurred.[3]

In addition to a general impaired state of health, arising, probably, from faulty aëration of the blood, and to phthisis and other lung affections, which may reasonably be believed to have their origin in the constant breathing of air vitiated by the organic vapors and particles arising from the person, it has long been considered, and apparently quite correctly,

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[1] Statistical Reports on the Health of the Navy, and especially Gavin Milroy's pamphlet on the Health of the Royal Navy, 1862, pp. 44 and 54.

[2] Trans. of the Epidem. Soc., vol. ii., p. 142.

[3] Report by Dept. Surg.-General Simpson.

that such an atmosphere causes a more rapid spread of several specific diseases, especially typhus exanthematicus, plague, small-pox, scarlet fever, and measles. This may arise in several ways; the specific poison may simply accumulate in the air so imperfectly changed, or it may grow in it (for though there may be an analogical argument against such a process, it has never been disproved, and is evidently not impossible); or the vitiated atmosphere may simply render the body less resisting or more predisposed.

(*b*) *Air rendered Impure by Exhalations from the Sick.*—The air of a sick ward, containing as it does an immense quantity of organic matter, is well known to be most injurious. The severity of many diseases is increased, and convalescence is greatly prolonged. This appears to hold true of all diseases, but especially of the febrile. At a certain point of impurity, erysipelas and hospital gangrene appear. The occurrence of either disease is, in fact, a condemnation of the sanitary condition of the ward. It has been asserted that hospital gangrene is a precursor of exanthematic typhus,[1] but probably the introduction at a particular time of the specific poison of typhus was a mere coincidence. But, doubtless, the same foul state of the air which aids the spread of the one disease would aid also that of the other.

When hospital gangrene has appeared, it is sometimes extremely difficult to get rid of it. Hammond[2] states that in a ward of the New York City Hospital, where hospital gangrene had appeared, removal of the furniture and patients did not prevent fresh patients being attacked. Closing the ward for some time and whitewashing had no effect. The plastering was then removed, and fresh plaster applied, but still cases recurred. At last the entire walls were taken down and rebuilt, and then no more cases occurred.

It is now well known that by the freest ventilation, *i.e.*, by treating men in tents or in the open air, hospital gangrene can be entirely avoided.[3] The occurrence of hospital gangrene in a tent is a matter of the rarest occurrence.

(*c*) *Air rendered Impure by Combustion.*—Of the products of combustion which pass into the general atmosphere, the carbon dioxide and monoxide are so largely and speedily diluted that it is not likely they can have any influence on health. The particles of carbon and tarry matter, and the sulphur dioxide, must be the active agents if any injury results. It has been supposed that the molecular carbon and sulphur dioxide, instead of being injurious, may even be useful as disinfectants, and we might *à priori* conclude that to a certain extent they must so act; but certainly there is no evidence that the smoky air of our cities, or of our colliery districts, is freer from the poisons of the chief specific diseases than the air of other places. It has been supposed, indeed, that the air of large cities is particularly antagonistic to malaria, and it is true that they have less diphtheria, in this country, than the rural districts, but there are probably other causes acting in those cases. The solid particles of carbon, and the sulphur dioxide, may, on the other hand, have injurious effects. It is not right to ignore the mechanical effect of the fine powder of coal so constantly drawn

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[1] See Guillemin, Recueil de Mémoires de Med. Ch. and Pharm. Militaires, No. 159, 1874.

[2] On Hygiene, p. 172.

[3] See Vol. II., chapter on HOSPITALS, and Professor Jüngken's Address on Pyæmia, in the Sydenham Society Year-Book for 1862, p. 213; and Report on Hygiene, by Dr. Parkes in the Army Medical Report for 1862 (vol. iv.).

into the lungs, and even the possibility of irritation of the lungs from sulphur dioxide. Certain it is, that persons with bronchitis and emphysema often feel at once the entrance into the London atmosphere ; and individual experience will probably lead to the opinion that such an atmosphere has some effect in originating attacks of bronchitis, and in delaying recovery. But statistical evidence of the effect of smoky town atmospheres in producing lung affections on a large scale cannot be given, so many are the other conditions which complicate the problem. There is, however, no doubt of the evil effect of the London atmosphere during dense fogs ; witness the effect upon the animals at the cattle show at Islington in December, 1873, and the increased mortality from lung diseases during foggy weather.

The effect of breathing the products of combustion, of gas especially, is more easily determined. In proportion to the amount of contamination of the air, many persons at once suffer from headache, heaviness, and oppression.

Bronchitic affections are frequently produced, which are often attributed to the change from the hot room to the cold air, but are really probably owing to the influence of the impure air of the room on the lungs.

The effects of constantly inhaling the products of gas combustion may be seen in the case of workmen whose shops are dark, and who are compelled to burn gas during a large part of the day ; the pallor, or even anæmia and general want of tone which such men show, is owing to the constant inhalation of an atmosphere so impure.

(*d*) *Air rendered Impure by the Gas and Effluvia from Sewers and House Drains.*—Cases of asphyxia from hydrogen sulphide, ammonium sulphide, carbon dioxide, and nitrogen (or possibly rapid poisoning from organic vapors), occasionally occur both in sewers and from the opening of old cesspools. In a case at Clapham, the clearing out of a privy produced in twenty-three children violent vomiting and purging, headache, and great prostration, and convulsive twitchings of the muscles. Two died in twenty-four hours.[1]

These are instances of mephitic poisoning in an intense degree ; but when men have breathed the air of a newly opened drain in much smaller amounts, marked effects are sometimes produced ; languor and loss of appetite are followed by vomiting, diarrhœa, colic, and prostration. The effluvia which have produced these symptoms are usually those arising from a drain which has been blocked for some time. When the air of sewers penetrates into houses, and especially into the bed-rooms, it certainly causes a greatly impaired state of health, especially in children. They lose appetite, become pale and languid, and suffer from diarrhœa ; older persons suffer from headaches, malaise, and feverishness ; there is often some degree of anæmia, and it is clear that the process of aëration of the blood is not perfectly carried on.[2]

In some cases decided febrile attacks lasting three or four days, and attended with great headache and anorexia, have been known. Houses into which there has been a continued escape of sewer air have been so notoriously unhealthy that no persons would live in them, and this has not been only from the prevalence of fever, but from other diseases. Brigade-Surgeon Marston, in his excellent paper on the Fever of Malta,[3]

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[1] Health of Towns Report, vol. i., p. 139.

[2] Ibid. See especially the evidence of Rigby, vol. i., p. 151, and of Aldis, vol. i., p. 115.

[3] Army Med. Report for 1861, p. 486.

tells us that when typhoid fever broke out at the Fort of Lascaris, from the opening of a drain, other affections were simultaneously developed, viz., "diarrhœa, dysentery, slight pyrexial disorders, and diseases of the primary assimilative organs." A close examination and analysis of the affections produced by the inhalation of sewer air, would probably much enlarge this list; and the class of affections resulting from this cause, to which it may be difficult to assign a nosological name, will be found to be essentially connected with derangement of the digestive rather than with the pulmonary system.

Dr. Herbert Barker[1] has attempted to submit this question to experiment by conducting the air of a cesspool into a box where animals were confined. The analysis of the air showed the presence of CO_2, hydrogen sulphide, and ammonium sulphide. The reaction of the gas was usually neutral, sometimes alkaline. The gas was sometimes offensive, so that organic vapors were probably present; but no analysis appears to have been made on this point. Three dogs and a mouse were experimented on; the latter was let down over the cesspool, and died on the fifth day. The three dogs were confined in the box; they all suffered from vomiting, purging, and a febrile condition, which, Dr. Barker says, "resembled the milder forms of continued fever common to the dirty and ill-ventilated homes of the lower classes of the community." But the effects required some time, and much gas for their production. Dr. Barker attributes the results, not to the organic matter, but to the mixture of the three gases, and specially to the latter two.

The effect on the men who work in sewers which are not blocked, or temporarily impure from exceptional disengagement of hydrogen sulphide from any cause,[2] has been subject to much debate. The air in many sewers in London is not very impure; the analyses of Letheby and Miller have shown that generally the amount of CO_2 is very little in excess of that in the external air, and that there is hardly a trace of hydrogen sulphide or of fetid organic effluvia. The air in the house drains is often, in fact, more impure than that of the main sewers. This is the case also in the other places, and is to be accounted for by the numerous openings in the sewers, from the porosity of the walls, from the continual ventilation produced by the air being drawn into houses, and from the amount of water in the sewers being often so great, and its flow so rapid, as to materially lessen the chances of generation of gas. The evidence is, on the whole, opposed to the view that sewer-men suffer in health in consequence of their occupation. Thackrah states[3] that sewer-men are not subject to any disease (apart from asphyxia), and are not short-lived. He cites no evidence. Parent-Duchâtelet[4] came, on the whole, to the same conclusion as regards the sewer-men of Paris in 1836. He says that there are some men so affected by the air of sewers that they can never work in them; but those who can remain suffer only from a little ophthalmia, lumbago, and perhaps

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[1] Malaria and Miasmata, 1863, p. 176 et seq.

[2] Fatal cases have occurred both in London and Liverpool sewers from the rapid evolution of SH_2, either from gas liquid, or, in Liverpool, from the action of acids passing into the sewers, and meeting with sulphide of calcium in the refuse derived from alkaline manufactories.

[3] The Effects of Arts, Trades, and Professions on Health, 1832, p. 118.

[4] Hygiène Publique, vol. i., p. 247 (1836). The conclusions of Parent-Duchâtelet are not entirely justified by his evidence. The number of men he examined was small, and many of them had been employed for a short time only in the sewers; it also appeared that a considerable number had actually suffered from bilious and cerebral affections. (See the former editions of this work.)

sciatica. They consider otherwise their occupation not only innocent, but as favorable to health. The only fact adverse to this seemed to be that the air of the sewer greatly aggravated venereal disease, and those who persisted in working with disease on them inevitably perished. The working in deep, old sewage matter produced an eruption on the parts bathed by the mud, which resembled itch sometimes, or was phlyctenoid in character.

A more recent inquiry conducted into the health of the sewer-men in London did not detect any excess of disease among them,[1] and in Liverpool also the sewer-men are said to have good health. The workmen employed at the various sewage outfalls, who, though not in the sewers, breathe the effluvia arising from the settling tanks, do not find it an unhealthy occupation.

It does not appear, therefore, that at present the workmen connected with fairly ventilated sewers show any excess of disease; at the same time, it must be allowed that the inquiry has not been very rigorously prosecuted, and that the length of time the men work in sewers, their average yearly mortality, discharge from sickness, loss of time from sickness, and the effect produced on their expectation of life, have not been perfectly determined.

The air of sewers passing into houses aggravates most decidedly the severity of all the exanthemata—erysipelas, hospital gangrene, and puerperal fever (Rigby); and it has probably an injurious effect on all diseases. That pneumonia may be produced is shown by the case of the East Sheen School.

Two special diseases have been supposed to arise from the air of sewers and fecal emanations, viz., *diarrhœa* and *typhoid* (enteric) fever.

With regard to the production of diarrhœa from fecal emanations, it would seem that the autumnal diarrhœa of this country is intimately connected with temperature,[2] and usually commences when the thermometer is persistently above 60°, and when there is, at the time, a scarcity of rainfall. It is worst in the badly sewered districts, and is least in well-drained districts, and in wet years. It has been checked in London by a heavy fall of rain. All those points seem to connect it with fecal emanations reaching a certain rapidity of evolution in consequence of high temperature, deficient rain, and perhaps relative dryness of the atmosphere. At the same time, there is a connection between this disease and impure water. It may own a double origin, and in a dry season both cases may be in operation.

That enteric fever may arise from the effluvia from sewers is a doctrine very generally admitted in this country, and is supported by strong evidence. There are several cases on record in which this fever has constantly prevailed in houses exposed to sewage emanations, either from bad sewers or from want of them, and in which proper sewerage has completely removed the fever.[3] Many of these cases occurred before the

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[1] In reference to this point, however, a writer in the Lancet (April, 1872) very justly pointed out that the statistics are very imperfect, in taking no notice of men who have been discharged or who have died.

[2] Ransom and Vernon, Influence of Atmosph. Changes on Dis., p. 3.

[3] In Health of Towns Reports and Evidence, Mr. Simon's Reports, Dr. Letheby's Reports, Dr. Acland's Reports on Fevers in Agricultural Districts, and the Reports of the Medical Officer to the Privy Council, will be found abundant evidence in support of this assertion. Many provincial towns in England could give similar evidence, as Norwich. (See Dr. Richardson's Report, Medical Times and Gazette, January, 1862.)

water-carriage of typhoid was recognized, but yet the connection between the sewage emanation and the fever seems undoubted.

This evidence is supported by cases in which the opening of a drain has given rise to decided typhoid fever,[1] as well as to a very fatal disease (probably severe typhoid), in which coma is a marked symptom. So also in some instances (Windsor and Worthing),[2] the spread of enteric fever has evidently been owing to the conveyance of effluvia into houses by the agency of unventilated sewers. In a case, from private information, an outbreak of enteric fever in a training-school was localized in certain parts of the school (whereas the drinking-water was common to all), and was traced to imperfection of traps in those parts of the house which were affected. In this case the drains led down to a large tank at some distance, and at a much lower level, and the smell of the effluvia was so slight that at first it was not believed that the drains could be out of order. A very good case is given by Surgeon Page,[3] late 6th Dragoons, in his description of an outbreak of typhoid fever at Newbridge, following discontinuance of the use (on account of repairs) of a ventilating shaft for the sewers. Sewer-gas got into the barracks, and several cases (some fatal) of typhoid fever occurred. Other possible causes were carefully inquired into and eliminated.[4] These two classes of fact seem decidedly to show a causal connection between the effluvia from sewers and excreta and enteric fever, and they are supported by the statistical evidence which proves that the prevalence of typhoid fever stands in a close relation to the imperfection with which sewage matters are removed. The army statistics give excellent instances of this, and the evidence produced by Dr. Buchanan of the prevalence of typhoid fever before and after sewerage of a town is to the same effect.[5]

The persistent existence of enteric fever at Eastney barracks, Portsmouth, appears to have been traceable to sewer air driven back into the quarters by the tide, there being no traps or ventilating openings. Since October, 1878, when the drains were put in better order, and better flushed and ventilated, there has been no fever.[6]

German writers have lately commented much upon the view that there is a connection between sewer air and enteric fever, and reference may be especially made to the papers of Soyka, Renk, A. de Rozsahegyi and Lissauer.[7] Their contention is that enteric fever is not due to the influence of sewer air, because it is rare that such air gets into houses, and experiments are cited to prove this. It is, however, admitted and demonstrated by Soyka in the tables which he gives, that a similar improvement

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The case of Calstock, in Devonshire, may be also noted. It used to be always liable to outbreak of typhoid fever, but after the drainage of the place the fever disappeared. (Bristowe, in Trans. of Epid. Soc., vol. i., p. 396.) Murchison not only adopted this view, but even proposed to give the term "pythogenic fever" to typhoid.

[1] For references to illustrative cases, see 5th edition of this work, p. 128, note.

[2] Ninth Report of the Medical Officer to Privy Council, p. 44.

[3] Army Medical Report, vol. xv., p. 301.

[4] An outbreak at Kinsale, apparently due to sewer effluvia, is narrated by Surgeon-Major Wallace, Army Med. Reports, vol. xvii., p. 55. The inquiry seems to have been very carefully made.

[5] Ninth Report of Medical Officer to the Privy Council, p. 44. In twenty-one English towns the average reduction of typhoid mortality after sewage was 45.4 per cent. In many of the towns an improved water supply was introduced at the same time, but the purification of the air by sewage and cleanliness has, it is believed by Buchanan, "been most uniformly followed by a fall in the prevalence of typhoid."

[6] See "Report on Hygiene," A.M.D. Reports, vol. xx., p. 222.

[7] Deutsche Vierteljahrschrift für Offentliche Gesundheitspflege, 1881.

in the health of towns has followed the introduction of proper drainage in the cities of Germany as has been observed in this country. This is attributed to the cleansing of the soil and the atmosphere by the removal of the sewage matter, although they still insist upon the essentially local or *topical* character of the disease. Von Nägeli [1] positively denies the possibility of specific disease being conveyed through emanations from drains or cesspools.

Although it seems difficult not to admit that the effluvia from the sewers will produce typhoid, there are yet some remarkable facts which can be cited on the other side.

It has been denied by Parent-Duchâtelet and by Guy [2] that typhoid fever is more common among sewer-men than others, and later inquiries among the sewer-men of London seem to bear out the assertion. But, as already stated, the air of London sewers is really tolerably pure ; and some of the men may be protected by previous attacks, for typhoid fever is a most common disease among the poorer children in London. Murchison [3] and Peacock have also stated, on the other side, that enteric fever is not uncommon among sewer-men. This argument, therefore, is not of great weight.

The evidence is very strong that the men employed at the sewage tanks and on the sewage farms, and their families, do not show an unusual amount of typhoid ; nor do the persons living in adjacent houses. Now, if sewage emanations can cause typhoid fever, it might be expected that we should by this time have had plenty of evidence of this special effect. Again, in our rural villages, and in many farm-houses, the excreta of men and animals literally cover the ground, and it might have been anticipated that enteric fever would never be absent. If this is the case in this country, it is still more so in China, where the excreta are so carefully stored and applied to land. In a report made by various medical officers, the writers state that, in Chinese villages surrounded with excreta, where the contamination of the air by fæcal emanations is very great, there is no typhoid fever. And as typhoid is well known in other parts of China, the absence is not owing to any peculiarity of climate preventing the appearance of the fever.[4]

We have, then, counterfacts which must be allowed to be of considerable weight. Any explanation, to be satisfactory, must not ignore one set of facts, but must impartially include both.

The possibility that the adult persons submitted to sewage emanations may have had typhoid fever in early life, and are therefore insusceptible, may explain some cases of escape, even when fæcal emanations are constantly breathed. But it would be impossible to extend this argument to the cases of immunity in children, unless we suppose that typhoid fever in children is constantly overlooked, and is as common as measles, which seems unlikely.

It has been supposed that there is an essential difference when animal and vegetable substances are decomposing in covered places and in the open air.[5] It is evident that the physical conditions will be widely dif-

[1] Die Niederen Pilze, 1877, p. 215 et seq.

[2] Journal of the Statistical Society, 1848.

[3] On Fevers, p. 453.

[4] See Reports by Drs. Miller and Manson, for Shanghai and Amoy, in the Customs Gazette of China, July to September, 1871.

[5] This is the view taken in the Second Report of the State Board of Health of Massachusetts. From an inquiry in most of the large cities of that State, the conclusion is drawn that it is putrefaction of animal and vegetable substances, under cover, which gives typhoid.

ferent in the two cases. In underground channels there is greater mean temperature, more moisture, and a more stagnant atmosphere. In the open air, while there may be heat from the sun's rays, this may restrain putrefaction; while the coldness of the nights and the much greater movement and dryness of the air, may hinder the formation or lessen the chance of reception of any fever-causing substance developed during the putrefaction. At first sight, there appears to be much in favor of this view, and it would explain the greater chance there appears to be of effluvia coming from sewers causing typhoid fever than when the effluvia came from excreta in the open air. But it does not meet two undoubted facts, viz., that there are cases in which sewer air is breathed without causing typhoid, and the occasional severe outbreaks of typhoid in villages without sewers, and where there is no putrefaction under cover.

That the importation of typhoid fever into places previously free for years is followed by outbreak[1] is quite certain. In many of these cases, as in the excellent instance at Steyning, recorded by Whitley,[2] all the conditions of accumulated sewage, etc., which are supposed to produce typhoid fever, were present for years, and yet no fever resulted. Then a patient came from a distance with typhoid fever, and the disease spread through the village, either through the medium of the water (as is perhaps most common), or through the air. These instances are so numerous that the entrance of a fresh agent must be admitted, and if so, the series of events becomes quite intelligible.

The doctrine that a specific cause is necessary for the production of typhoid fever; that this cause is present in the intestinal discharges, and that sewers and fæcal effluvia, and fæcal impregnation of water, are thereby the channels by which this specific cause reaches the body of a susceptible person (*i.e.*, of a person who has not previously had the disease), will be found to explain almost all the events which have been recorded in connection with the origin of typhoid fever.

There are, however, still some difficulties. There are instances in which typhoid fever arises from sewer air without any possibility of tracing the entrance of a person with the disease.[3] Sometimes, as in the case of an isolated house in the country, it seems most difficult to believe that any such entrance could have taken place. It must, however, be remembered that the carriage of the "contagion" takes place in so many ways, that it is impossible always to trace it. In the case of typhoid fever, the stools are not only infectious during the height of the disease, but probably during the early period of recovery; and the disease itself is also often so slight that persons move about, and believe they have only an attack of diarrhœa. Again, the frequent journeying from place to place exposes all persons to a greater chance of inhaling the typhoid effluvia, and the real source of the disease may be far removed from the place which is actually suspected.

There are, again, cases in which typhoid fever occurs in persons who have not been exposed apparently to sewer air, or fæcal emanations, or to the charge of any typhoid contagion. Dr. Gordon Hardie has recorded two cases of this kind of soldiers attacked during imprisonment. Such cases can only be explained either by supposing an incubative period of

[1] The cases recorded sixty years ago by Bretonneau have been confirmed by many observations since.

[2] From the Report of the Medical Officer to the Privy Council, p. 43.

[3] Ranke admits the possibility of spontaneous origin of typhoid, but thinks it spreads more frequently through air than any other way.

extraordinary length, or an origin apart altogether either from fæcal emanations or a prior case of the disease.

Admitting, however, that there are still difficulties to be explained by future observation, it seems clear that the theory of a specific cause reproducing itself in the intestines and contained in the discharges, and naturally therefore, connected more or less closely with excreta and sewers, and sometimes with drinking-water, is that which best meets the facts which have been most faithfully reported in outbreaks of typhoid fever. The evidence of the carriage of a cause of this kind in water strongly supports this view.

(*e*) *Emanations from Fæcal Matter thrown on the Ground.*—Owing, doubtless, to the rapid movement of the air, there is no doubt that the excreta of men and animals thrown on the ground and exposed to the open air are less hurtful than sewer air, and probably in proportion to the dilution.

When there are accumulations in close courts, small back-yards, etc., the same effects are produced as by sewer air, and many instances are recorded in the Health of Towns Report. When fæcal matters are used for manure, and are therefore speedily mixed with earth, they seldom produce bad effects. Owing, doubtless, to the great deodorizing and absorbing powers of earth, effluvia soon cease to be given off. An instance is, however, on record in which two cases of typhoid were supposed to arise from the manuring of an adjacent field. Dr. Clouston has also shown by evidence, which seems very strong, that dysentery was produced in an asylum by the exhalations from sewage, which was spread over the ground (a stiff brick clay subsoil) about 300 yards from the asylum. The case seems a very convincing one, as the possibility of the action of other causes (impure water, bad food, etc.) was excluded. This is a point on which more evidence is desirable. It is stated in some works that disease is frequently produced by the manuring of the ground, but there seems to be no satisfactory evidence of this. On the other hand, Dr. A. Carpenter shows, from the history of Beddington sewage farm, that no harm to the neighborhood has accrued from the irrigation with the Croydon sewage during twenty years.[1] It has been said that if the sewage matter can be applied while perfectly fresh to the ground, no harm results; but if decomposition has fully set in, it is not so completely deodorized by the ground.[2] In China, where fæcal matter is so constantly applied in agriculture, the air is often filled with very pungent effluvia, yet no bad effect is produced.[3]

(*f*) *Emanation from Streams polluted by Fæcal Matter.*—The evidence on this point is contradictory. Parent-Duchâtelet, in 1822,[4] investigated the effect produced on the health of the inhabitants of the Faubourg St. Marceau, in Paris, by the almost insupportable effluvia arising from the Rivière de Bièvre, which received a large portion of the sewage of the quarter. He asserts that the health was not at all damaged, though he admits that there is truth in the old tradition at the Hôtel Dieu, that the cases from St. Marceau were more severe than from any other place.

Dr. M'William found that the emanations from the Thames in 1859–60

[1] The Utilization of Town Sewage by Surface Irrigation, by A. Carpenter, M.D., Trans. Internat. Medical Congress, London, 1881, vol. iv.

[2] See chapter on SEWAGE, Vol. II.

[3] Dr. A. Jamieson's "Report on the Health of Shanghai for the Half-year ending September, 1870," China Customs Gazette for 1870; Shanghai, 1871.

[4] Hygiène Publique, p. 98.

had no deleterious effect on the health of the Custom-House men employed on the river. The amount of diarrhœa was even below the average.

Mr. Rawlinson states [1] that a careful house-to-house visitation had been made in some of the worst districts of Lancashire (in Manchester, on the banks of the Medlock, for instance) without finding any great excess of disease.

On the other hand, in the reports of Sir H. De la Beche and Dr. Lyon Playfair,[2] is some strong evidence that the general health of the people suffered from the emanations of the putrid streams of the Frome, and the tributaries of the Irk and Medlock; that they were pale, in many cases dyspeptic; that fevers (typhoid) prevailed on the banks is asserted by some observers, but rather doubted by others; but none seem to have any doubt that the fevers, when they occurred, were much worse. Cholera in Manchester was severe along the banks of some of these streams, but that might have been from the water being drunk. In 1858 also, Dr. Ord [3] observed that a large number of the men employed on the Thames were affected by the effluvia; the symptoms being languor and depression, followed by nausea and headache, aching of the eyeballs, and redness and swelling of the throat. Diarrhœa was rare. In 1859 these symptoms were not observed, though the state of the river was worse. Were they then really caused by the effluvia in 1858?

It is very likely that the discrepancy of evidence may arise from the amount of water which dilutes the fæcal matter being much greater in some cases than others. In the case of the Thames, the dilution was after all very great, and this was the case, in part at any rate, in the Bièvre, as the stream was in some places 6 and 7 feet deep. The evaporation from such a body of water, however offensive it may be, must be a very different thing from the effluvia coming off from the masses of organic matter laid bare by the almost complete drying up of streams into which quantities of fæcal matter are discharged. When sewage matter is poured into the sea, and washed back by the tide, it becomes a source of danger.

(*g*) *Effect of Manure Manufactories.*—The manure manufactories at present existing in this country do not appear to produce any bad effects. They are generally at some little distance from towns, and the effluvia are soon diluted. The Secretary of the Hyde Manure Company stated that while the works were in operation no bad effects were observed. But if situated in towns they are nuisances, and may be hurtful. In 1847 evidence was given to show that a manure manufactory situated in Spitalfields, and about 100 feet from the workhouse, caused bad diarrhœa whenever the wind blew in that direction, and 12 cases of "spontaneous gangrene" (!) which had appeared among children were attributed to it. The cases of disease in the workhouse infirmary also acquired, it was said, a malignant and intractable character.[4] In France the workmen engaged in the making of "poudrette" do not in any way suffer, except from slight ophthalmia.[5] Parent-Duchâtelet [6] (on very slight evidence indeed) thought the

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[1] Report of Committee on Sewage, 1864, p. 174, Question 3997.

[2] Second Report of the Health of Towns Commission, pp. 261 and 347.

[3] Trans. Social Science Association, 1859, p. 571.

[4] Medical Gazette, December, 1847.

[5] Parent-Duchâtelet; Patissier. See also Tardieu, Dict. d'Hygiène, t. iv., p. 453. Tardieu, in 1862, writes: "We do not hesitate to affirm that the exhalations from these manufactories (voiries) exercise no injurious action either on man or vegetation." But it must be remembered that these places are excellently conducted; ventilation is good, and the fæcal matter is soon subjected to processes which prevent its decomposition.

[6] Hyg. Publique, t. ii., p. 276.

emanations were even beneficial in some diseases, and Tardieu seems inclined to support this opinion. When the poudrette is decomposing, and large quantities are brought into small spaces, as on board ship, serious consequences may certainly result. Parent-Duchâtelet records two cases of outbreaks on board ships carrying poudrette which fermented on the voyage; one vessel, the "Arthur," lost half her crew (number not known), and the rest were in a state of deplorable health; the men who unloaded the cargo were also affected. The symptoms are not recorded; but, in a smaller vessel, where all on board (5) were similarly affected, the disease put on the appearance of "an adynamic fever." There was intense pain of the head and of all the limbs, vomiting, great prostration, and in two cases severe diarrhœa. These symptoms are very similar to those already mentioned as produced in the children at Clapham by the opening of a privy. In bone manure factories it has been shown that arsenic is given off in the fumes in considerable quantity, arising from the use of impure sulphuric acid.[1]

(*h*) *The Air of Graveyards.*—There is some evidence that the disturbance of even ancient places of sepulture may give rise to disease. Vicq d'Azyr refers to an epidemic in Auvergne caused by the opening of an old cemetery; the removal of the old burial-place of a convent in Paris produced illness in the inhabitants of the adjoining houses.[2] In India, the cantonment at Sukkur was placed on an ancient Mussulman burial-ground, and the station was most unhealthy,[3] especially from fevers.

The effect of effluvia from comparatively recent putrefying human bodies has been observed by many writers. Rammazzini[4] states that sextons entering places where there are putrefying corpses are subject to malignant fevers, asphyxia, and suffocating catarrhs; Fourcroy remarks that there are a thousand instances of the pernicious effects of cadaveric exhalations; and Tardieu[5] has collected a very considerable number of cases, not only of asphyxia, but of several febrile affections produced by exhumations and disturbance of bodies. Mr. Chadwick,[6] and the General Board of Health,[7] also summed up evidence which showed that in churchyards thickly crowded with dead, vapors were given off which, if not productive of any specific disease, yet increased the amount both of sickness and mortality. In some instances this might have been from contamination of the drinking-water; but in other cases, as in the houses bordering the old city graveyards, where the water was supplied by public companies, the air also must have been in fault. In the houses which closely bordered the old city yards, which were crowded with bodies, cholera was very fatal in 1849[8], and, according to some practitioners, no cases recovered. All other diseases in these localities were said to have assumed a very violent and unfavorable type. Hirt says, on the other hand, that when gravediggers are protected from the acute effects of carbon dioxide, their calling is not unhealthy; their death-rate he gives at 17 per 1,000, and their mean duration of life at 58–60 years. This, however, is in Germany, where, as he admits, there is less crowding of graveyards than in England or

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[1] On the Presence of Arsenic in the Vapors of Bone Manure, by James Adams, M.D. 1876, etc.

[2] Tardieu, Dict. d'Hygiène, t. i, p. 517.

[3] Norman Chevers, European Soldiers in India, p. 404.

[4] Maladies des Artizans, p. 71.

[5] Dict. d'Hygiène, 1862, t. iii., p. 463 et seq.

[6] Report on Interments in Towns.

[7] Report on Extramural Sepulture, 1850.

[8] S. Smith and Sutherland's Reports on Extramural Interment, p. 12. See also Sutherland's Report on Cholera, 1850, p. 27.

France. Nägeli, arguing probably from similar data, thinks that graveyards may exist in the midst of towns without danger to health, provided precautions be taken with reference to the drainage and ventilation of the soil.

(*i*) *Effluvia from Decomposing Animals.*—On this point there is some discrepancy of evidence.

In 1810, Deyeux, Parmentier, and Pariset gave evidence to show that the workmen in knackeries are in no way injured. Parent-Duchâtelet, from his examination of the health of the men employed at the knackery and slaughter-house at Montfaucon, came also to the conclusion that their health was not affected. It should be mentioned that this knackery is remarkably well placed for ventilation, and is excellently conducted ; putrid remains, in the proper sense of the word, do not now exist in any knackery in or near Paris ; the workmen are well paid and well fed, and are therefore prepared to bear the effect of any injurious effluvia. It has been stated, however, that in the Hôtel Dieu, the patients used to suffer when the wind, loaded with effluvia, blew from Montfaucon (Henry Bennet). Tardieu, from a late re-examination of the question, confirms Parent's conclusions,[1] except as regards glanders and malignant pustule, touching which Parent-Duchâtelet's evidence was as usual negative. Tardieu,[2] however, states that many examples occur in the French knackeries of the transmission of these diseases, though glanders and farcy are less frequently caught in knackeries than in stables. No analysis has yet been made of the air of knackeries.

Parent-Duchâtelet[3] is also often quoted, as having proved that the exposure of the remains of 4,000 horses, killed in the battle of Paris in 1814, produced no bad effects. These horses were killed on March 30th, and were burnt on the 10th and 12th of April. They gave out " une odeur infecte," which produced no bad results on those who collected the bodies. Parent-Duchâtelet inquired particularly whether typhus was produced by effluvium, and proved that it was not ; a conclusion conformable to our present doctrine. He did not, however, do more than examine the registers of deaths of the three years before, during, and after the battle, and found no evidence for increased mortality. The utmost this observation shows is, that no typhus was produced ; and that the amount of decomposition, caused by eleven days of hot weather, did not affect those concerned in collecting and burning the bodies.

On the other hand, the experience of many campaigns, where soldiers have been exposed to the products of an advanced putrefaction of horses, shows that there is a decided influence on health. Pringle especially noticed this ; and in many subsequent campaigns this condition has been one of the causes of insalubrity. Diarrhœa and dysentery are the principal diseases ; but all affections are increased in severity. At the siege of Sebastopol, where, in the French camp, a great number of bodies of horses lay putrefying on the ground, Reynal[4] describes the effect as disastrous, and even conjectures that the spread of typhus was connected with this condition, though this is unlikely.

(*k*) *Air of Brickfields and Cement Works.*—The peculiar smell of brickfields cannot be owing to carbon dioxide or monoxide, or to hydrogen sulphide or sulphur dioxide (the gases evolved from the kilns) ; but its exact cause is not known. The air, at its exit from the chimney of furnaces and

[1] Dict. d'Hygiène, t. iv., p. 468.
[2] Op. cit., t. iv., p. 468.
[3] Dic. d'Hygiène, t. i , p. 47.
[4] Tardieu, Dict. d'Hygiène, t. ii., p. 221.

kilns, is rapidly fatal; but so rapid is its ascension, dilution, and diffusion, that at a little distance it is respirable. In almost all the actions against the owners of brickfields nothing more than a nuisance has been established, and this not in the legal sense. The smoke and gases from cement works, however, destroy neighboring vegetation. The smell can be perceived for several hundred yards.[1] In the north of France it is ordered that no kilns shall be within 50 metres ($54\frac{1}{2}$ yards) of a public road; and the kilns are lighted only at night.

(*l*) *Air of Tallow-makers, Bone-burners, etc.*—In many trades of this kind large quantities of very disagreeable animal vapors are produced, which spread for a long distance, and are most disagreeable. Although a nuisance, it is difficult to bring forward positive evidence of insalubrity. But the odor is so bad that in France rules are in force to oblige the vapors to be condensed or consumed,[2] and if in the process any water is contaminated with fatty acids, it is neutralized with lime. M. Foucon has figured an apparatus which completely burns the animal vapors.[3]

(*m*) *Air of Marshes.*—It seems scarcely necessary to allude to this point, except to notice that in addition to paroxysmal fevers, it has been supposed that serous diarrhœa (a sort of dysenteria incruenta) and true bloody dysentery, are produced by malaria. Also that there is perhaps some connection with malaria and liver abscess (?). The breathing of marsh air also may produce an imperfect condition of nutrition, in which enlarged spleen plays a prominent part, and the mean duration of life is shortened.

(*n*) *Unknown Conditions of the Atmosphere.*—Occasionally, outbreaks of disease occur from impurities of the atmosphere, the nature of which is not known, though the causes giving rise to them may be obvious. Dr. Majer records a case of a school at Ulm, of sixty or seventy boys, where the greater number were suddenly affected, on a warm day in May, with similar symptoms—giddiness, headache, nausea, shivering, trembling of the limbs, sometimes fainting. The attack occurred again the next day, and a common cause was certain. The room was enclosed by walls, in a narrow space, where the snow had lain all the winter; the wall was covered with fungous vegetation, and with salts from the mortar. From the sudden entrance of warm weather, fermentation had set in, and a strong marshy smell was produced; the substances of whatever kind generated in this way accumulated in the narrow, ill-ventilated space. Removal to a healthier locality at once cured the disease.

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[1] At Southampton the smell is perceptible at a distance of two miles.

[2] Vernois, Hygiène Indus., t. ii., p. 60.

[3] Pappenheim's Beit. der Sanitat. Pol., Heft ii.

CHAPTER III.

VENTILATION.[1]

The term ventilation is not always used in the same sense. By some it is applied to the dilution and removal of all impurities which can collect in the air of inhabited rooms. The most common causes of such impurities are the respiration and cutaneous transpiration of men, the products of combustion of lights, the effluvia of simple uncleanliness of rooms or persons, the products of the solid or fluid excreta retained in the room, or, in hospital, discharges from the body or from dressings. In addition there may be special conditions which allow impure air to flow into a room, as from the basement of a house, from imperfectly trapped soil and waste pipes, or from other impurities outside a house.

It will be desirable, however, to restrict the term ventilation to the removal or dilution, by a supply of pure air, of the pulmonary and cutaneous exhalations of men, and of the products of combustion of lights in ordinary dwellings, to which must be added, in hospitals, the additional effluvia which proceed from the persons and discharges of the sick. All other causes of impurity of air ought to be excluded by cleanliness, proper removal of solid and fluid excreta, and attention to the conditions surrounding dwellings.

The subject of ventilation may be conveniently considered under the following heads :—

1. The quantity of fresh air required for the purposes defined above.
2. The mode in which this quantity may be supplied.
3. The method of examining whether ventilation is sufficient or not; in other words, ascertaining that the air of inhabited rooms is pure according to a certain standard. This will form the subject of a separate chapter.

SECTION I.

QUANTITY OF AIR REQUIRED.

1. QUANTITY REQUIRED TO DILUTE OR REMOVE THE RESPIRATORY IMPURITIES CAUSED BY HEALTHY PERSONS.

The impurities added to the air by respiration have been already enumerated.

The CO_2 which a human being adds to the air he dwells in, is not in itself an important impurity, the amount being too small to exercise much influence on health ; but it is practically in a constant ratio with the more important organic matter of respiration ;—and, as it is readily determined

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[1] For Army Regulations on Ventilation, see Vol. II., Book II., Chap. II.

with sufficient accuracy for practical purposes, it is taken as a convenient index to the amount of the impurities.[1]

Pettenkofer, whose experiments are still the most trustworthy, ascertained that a man of twenty-eight years of age, weighing 132 ℔ avoir., evolved per hour at night during repose 0.56 of a cubic foot of CO_2, and 0.78 in the day-time, using very moderate exertion ; during hard work the same man evolved 1.52 per hour. These amounts give the following :—

In repose	0.00424 cub. ft. of CO_2	per ℔	of body weight.
In gentle exertion....	0.00591	"	"	"
In hard work	0.01227	"	"	"

These figures are nearly in the ratio of 2, 3, and 6, and this may serve as a guide to the proportions of fresh air required. If now we take the average weight of adult males at 150 ℔ to 160 ℔, adult females at 100 ℔ to 120 ℔, and children at 60 ℔ to 80 ℔, we should have the following amounts of CO_2 evolved per hour in repose :—

Adult males	0.636 to 0.678	cubic foot.
Adult females	0.424 to 0.509	"
Children	0.254 to 0.339	"

The estimate for children is probably too little, as tissue change is more active in their case.

For a mixed community a general average of 0.6 of a cubic foot per hour may be adopted ; but for adult males, such as soldiers, it is advisable to adopt 0.7 to 0.72.

Taking the CO_2 as the measure of the impurity of the air vitiated by respiration and transpiration, in short from the person in any way, we have to ask, What is to be considered the standard of purity of air in dwelling-rooms? We cannot demand that the air of an inhabited room shall be absolutely as pure as the outside air ; for nothing short of breathing in the open air can insure perfect purity at every respiration.[2] In every dwelling-room there will be some impurity of air.

The practical limit of purity will depend on the cost which men are willing to pay for it. If cost is disregarded, an immense volume of air can be supplied by mechanical contrivances ; but there are comparatively few cases in which this could be allowed.

Without, however, attempting too much, it may be fairly assumed that the quantity of air supplied to every inhabited room should be great enough to remove all sensible impurity, so that a person coming directly from the external air should perceive no trace of odor, or difference between the room and the outside air in point of freshness. This is now pretty generally admitted as the most convenient practical standard, precautions being taken that the air-space be entered directly from the external air, or as nearly so as possible, for the sense of smell is rapidly dulled.

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[1] One of the earliest observers to recognize the value of carbonic acid as an index of purity, appears to have been F. de Blanc, whose memoir, Recherches sur la Composition de l'Air Confiné (1842), is cited by General Morin. He appears to have had clearer notions as to the amount of air necessary than most of his contemporaries

[2] Thus the carbonic acid in the air being taken at .04 per cent., and the carbonic acid of respiration being placed at .6 cubic feet in an hour, a man placed in a room of 1,000 cubic feet of air must receive no less than 1,000,000 cubic feet of outside air in an hour to reduce the carbonic acid to the standard (nearly .0401 per cent.) of the fresh air.—"On Ventilation and Cubic Space," by Dr. de Chaumont, Assistant Professor of Hygiene, Army Medical School, Edinburgh Med. Jour., May, 1867.

In a paper by Dr. de Chaumont,[1] it is shown, from a large number of observations (473 analyses), that the sense of smell carefully employed gives a very fair idea of the amount of impurity in an air-space. In those experiments the amount of CO_2 in the external air was determined at the same time, so that the respiratory impurity was accurately known. Dividing the observations into groups, the following results were obtained :—

	1. Fresh, or not differing sensibly from the outer air.	2. Rather close. Organic matter becoming perceptible.	3. Close. Organic matter disagreeable.	4. Very close. Organic matter offensive and oppressive; limit of differentiation by the senses.
Mean CO_2 per 1,000 vols. reduced to 0° Cent (=32° F.), due to respiratory impurity..................	0.1943	0.4132	0.6708	0.9054

It will thus be seen that the smell of organic matter is, on an average, perceptible to the sense of smell when the coincident CO_2, due to respiratory (or personal) impurity, reaches 0.1943 per 1,000 ; and that when it exceeds 0.9054, smell is no longer able to detect shades of difference. We may therefore take 0.2 per 1,000 in round numbers as the maximum amount of respiratory impurity admissible in a properly ventilated air-space.

Adopting, then, this standard as the measure of the permissible maximum of impurity, the next point is the quantity of pure external air which should pass through the air of a room, vitiated by respiration, per head per hour, in order to keep the CO_2 at this ratio, assuming a general average of 0.6 of a cubic foot per head per hour to be given out. The following table gives the answer to this question, under different conditions of cubic space :—

TABLE *to show the Degree of Contamination of the Air (in terms of* CO_2*) by Respiration, and the Amount of Air necessary to dilute to a given Standard of* .2 *per* 1,000 *Volumes of Air, exclusive of the Amount originally present in the Air.*

Amount of cubic space (= breathing space) for one man in cubic feet.	Ratio per 1,000 of CO_2 from respiration at the end of one hour, if there has been no change of air.	Amount of air necessary to dilute to standard of .2 during the first hour.	Amount necessary to dilute to the given standard every hour after the first.
100	6.00	2,900	3,000
200	3.00	2,800	3,000
300	2.00	2,700	3,000
400	1.50	2,600	3,000
500	1.20	2,500	3,000
600	1.00	2,400	3,000
700	0.86	2,300	3,000
800	0.75	2,200	3,000
900	0.67	2,100	3,000
1,000	0.60	2,000	3,000

For the sake of simplicity, the CO_2 naturally in the air has been disregarded, but, of course, there would be actually in the air from .3 to .4

[1] "On the Theory of Ventilation," Proceedings of the Royal Society, No. 168, p. 187, 1875, and No. 171, 1876.

volumes per 1,000 more from this source. Thus (if we take it at 0.4), in the room of 100 cubic feet, there would be at the end of an hour (.04+.6) .64 volume, or 6.4 per 1,000, and in the room of 200 cubic feet there would be .34 volume per cent., or 3.4 per 1,000. The above table is calculated from this formula.[1]

$$\frac{(\rho_1 - \rho)c}{\rho} = d$$

where ρ_1 = Respiratory impurity per 1,000 volumes existing in the air-space c, stated in terms of CO_2.
ρ = Admissible limit of respiratory impurity, that is, 0.2 per 1,000 volumes.
c = Air-space, in cubic feet.
d = Amount of fresh air required, in cubic feet.

Thus the difference between the actual ratio of vitiation and the admissible limit, multiplied by the capacity of the air-space and divided by the admissible limit, gives the amount of fresh air required.

Example: Let $\rho_1 = 1.$ and $c = 600$: then $\frac{1. - .2}{.2} = 4$, and $4 \times 600 =$ 2,400 cubic feet of air required.

This formula is, however, inconvenient in form, and gives to *cubic space* an apparent importance which, as we shall see further on, it does not possess. The following is therefore better, as it is of general application.

$$\frac{e}{\rho} = d$$

where e = the amount of CO_2 exhaled by one individual in an hour, ρ = the limit of admissible impurity (stated per cubic foot), and d = the required delivery of fresh air in cubic foot per hour. If ρ be expressed per 1,000 volumes, then d must be taken to represent the *number of thousands* of cubic feet of air. If now we take e at the general average of 0.6 of a cubic foot, then:

$\frac{0.6}{0.0002} = 3{,}000$ or $\frac{0.6}{0.2} = 3$ = number of *thousands* of cubic feet of air required.

This formula may also be used conversely, in order to find from the condition of the air the average amount of fresh air which has been hitherto supplied and utilized. For this purpose we simply substitute for ρ (the admissible limit) ρ_1, the observed ratio. Thus, let us suppose that ρ_1, the observed ratio of vitiation, was 0.7 per 1,000 vols., we should have:

$\frac{0.6}{0.7} = 0.857$ = *number of thousands* of cubic feet;

or 857 cubic feet of air per head per hour had been supplied and utilized during the time of occupation.

We can also calculate the probable condition of an air-space in which a given quantity of air is supplied: thus, $\frac{e}{d} = \rho_1$; taking the amount directed for soldiers in barracks, viz., 1,200 per hour, we have (assuming that e represents in this case 0.7)

$\frac{0.7}{1{,}200} = 0.000583$ CO_2 per cubic foot, or 0.583 per 1,000 vols.

[1] See Dr. F. de Chaumont's papers in the Lancet, September, 1866, and Edin. Med. Journal, May, 1867; also Professor Donkin's Memorandum in the Blue Book of the Committee on the Cubic Space of the Metropolitan Workhouses (1867).

Where the quantity e is less than the above amounts, as for instance in the case of children, we should have, assuming children to evolve 0.4 of a cubic foot, $\frac{0.4}{0.2} = 2 =$ *number of thousands* of cubic feet of air required.

For a long time after this subject first attracted attention the amount of fresh air supposed to be necessary was put at too low a figure. Even the figures of General Morin,[1] which were a great advance at the time, are insufficient. He proposed 2,118 cubic feet (60 cubic metres) for barracks at night, and Ranke adopts the same figures.

Roth and Lex[2] adopt the maximum of total impurity at .6 per 1,000, which includes 0.4 of initial CO_2; and as they estimate the expired CO_2 as 20 litres,[3] or .706 cubic feet (Eng.) per hour, they give the hourly quantity of air as 100 cubic metres, or 3,533 cubic feet.

It is highly desirable that some general agreement should be come to as to the amount of air necessary, even if it be admitted that the desired amount cannot always be obtained. If we adopt the following amounts of CO_2 as being evolved during repose, we shall not be far from the probable truth.

Adult males (say 160 ℔ weight)	0.7 of a cubic foot.
" females (" 120 ℔ ")	0.6 "
Children (" 80 ℔ ")	0.4 "
Average of a mixed community	0.6 "

Under those conditions the amount of fresh air to be supplied in health during repose ought to be—

For adult males	3,500 cubic feet per head per hour.
" " females	3,000 " " "
" children	2,000 " " "
" a mixed community ...	3,000 " " "

The amount for adult males as above given is just 100 cubic metres, or if we take it at 3,600 cubic feet, it is just one cubic foot per second. These numbers are easy to remember.

When we have to deal with places, the inmates of which are actively employed, such as workshops and the like, the amount of air supplied must be proportionately increased. We have seen that in light work the CO_2 evolved per hour is nearly 0.006 of a cubic foot per ℔ of body weight, and in hard work at least double that amount,—so that for a man of 160 ℔ weight we should have—

In light work	0.95 of a cubic foot of CO_2 evolved per hour.
In hard work	1.96 " " "

This would argue a delivery of fresh air as follows :—

In light work	4,750 cubic feet.
In hard work	9,800 "

It was stated long ago, from extensive observations, that in *mines*, if it was wished to keep up the greatest energies of the men, no less than 100 cubic feet per man per minute (=6,000 per hour) must be given ; if the

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[1] Rapport de la Commission sur le Chauffage et la Ventilation des Batimens du Palais de Justice, Paris, 1860 ; also Manual Pratique du Chauffage et de la Ventilation, 1874.

[2] Op. cit., p. 221.

[3] This amount is also adopted by General Morin.

quantity were reduced to one-third, or one-half, there was a serious diminution in the amount of work done by the men. This amount included, of course, all the air wanted in the mine for horses, lights, etc.[1]

The amount for animals is an important question which has been little studied. Märcker[2] gives the following from experiments :—

For *large* cattle (viz., oxen, etc.) 30 to 40 cubic metres per hour for every 1,000 ℔ weight, or 1 to 1½ cubic foot for every ℔ weight.

For *small* cattle (viz., sheep, etc.) 40 to 50 cubic metres per hour for every 1,000 ℔ weight, or 1½ to 1¾ cubic foot for every ℔ weight; the higher quantity being given on account of the more rapid tissue change in the smaller animals. These quantities seem absurdly small, and the chief reason for so limiting them seems to have been the fear of lowering the temperature too far. This is an erroneous view: animals properly fed will thrive better in a well-ventilated place at a low temperature than in a warmer place ill-ventilated. There seems no reason why the same rule should not apply to animals as to man, in which case something like 20 to 25 cubic feet per hour per ℔ of body weight ought to be supplied. A horse or a cow ought, therefore, to have from 10,000 to 20,000 cubic feet per hour,—in short, it ought to be practically in the open air.

2. ON THE QUANTITY OF AIR REQUIRED FOR LIGHTS, IF THE AIR IS TO BE KEPT PURE BY DILUTION.

Air must be also supplied for lights if the products of combustion are allowed to pass into the room. Wolpert has calculated that, for every cubic foot of gas, 1,800 cubic feet of air must be introduced to dilute properly the products of combustion; and this is not too much if we remember that a cubic foot of good coal gas produces about 2 cubic feet of carbon dioxide, and that sulphur dioxide and other substances may be also formed. A common small gas burner will burn nearly 3 feet per hour, and will consume 10 or probably 12 cubic feet in an evening (4 hours), and therefore from 18,000 to 21,600 cubic feet of air must be introduced for this purpose alone in the 4 hours, unless the products of combustion are removed by a special channel.[3] The power of illumination being equal, gas does not produce more CO_2 than candles (Odling), but usually so much more gas is burnt that the air is much more deteriorated; there is also greater heat and more watery vapor. The products should never be allowed to escape into the air of the room. Weaver has shown how important a source of impurity this is; and the bad effects of breathing the products of gas combustion are well known.

One ℔ of oil demands, for complete combustion, 138 cubic feet of air; and to keep the air perfectly pure, nearly as much air must be introduced for 1 ℔ of oil as for 10 feet of gas. In mines, 60 cubic feet per hour are allowed for each light; the lights generally are dim, and the amount of combustion is slight; but this seems an extremely small amount.

If gas is not burnt in a room, or in a very small amount, or if only candles or oil lamps are used, it is seldom necessary to take them into account in estimating the amount of air.

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[1] Proceedings of the Civil Engineers, vol. xii., pp. 298 and 308.

[2] Op. cit.

[3] See an elaborate table by M. Layet, Revue d'Hygiène, vol. ii., pp. 1096–7.

3. ON THE QUANTITY REQUIRED FOR THE RESPIRATION AND DILUTION OF THE EMANATIONS OF SICK MEN.

In making differential experiments among the healthy and the sick, it has been found [1] that among the former the smell of organic matter was still imperceptible when the air contained 0.208 per 1,000 of respiratory impurity as CO_2 ; but in hospitals containing ordinary cases it was quite distinct when the CO_2 reached 0.166. From this we may conclude that the minimum amount of fresh air for hospitals ought to exceed that required in health by at least *one-fourth*. If 3,000 cubic feet per hour be admitted as a general average in health, we may demand in round numbers 4,000 in sickness ; and if we have to deal with adult males only, such as soldiers, 4,500 per head per hour. When we have to deal with serious cases, a still greater amount must be given, reaching 5,000, 6,000, or even more if possible,—in fact, the supply should be unlimited. These views are in accordance with the results of experimental inquiry (Grassi in Paris ; Sankey in London ; Sutherland).

In some diseases, so much organic substance is thrown off, that scarcely any ventilation is sufficient to remove the odor. In some of the London hospitals Dr. de Chaumont found that there was still a close smell when 5,000 cubic feet and even more were supplied, but the distribution was not perfect. Even when 3,600 feet were supplied and utilized (as calculated from the CO_2) the ward was not free from smell. The best surgeons now consider an almost complete exposure of pyæmia patients to the open air the best treatment ; and it is well known that in typhus fever and (to a less extent) in typhoid, and also in small-pox and plague, this complete exposure of patients to air is the first important mode of treatment, before even diet and medicines. Even temperature must be sacrificed to a considerable extent, in order to obtain fresh air, if a choice requires to be made between the two.

Humidity.—The condition of the air as regards humidity is a matter of some importance, but has not hitherto been much considered. In Dr. de Chaumont's experiments the mean humidity, in rooms having less than 0.2 per 1,000 of respiratory impurity (reckoned as CO_2), was 73 per cent., at a temperature of 63° Fahr. This might be taken, provisionally, as a standard,[2] at least for climates like our own. In drier climates, however, as in America, such a condition would not be attainable in many cases, when the external air has a mean humidity of 40 or even 30 per cent. In Germany 50 per cent. is looked upon as an average humidity, whilst in England this would indicate an exceptionally dry atmosphere.

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[1] The Theory of Ventilation, by Dr. de Chaumont, Proc. Roy. Soc., loc. cit.

[2] From the state of the air as regards humidity, information may sometimes be obtained which might take the place of the CO_2 determination, in the absence of means for carrying out the latter. For instance, at St. Mary's Hospital, the air of the wards was found to have 78 per cent. of humidity, or 5.8 per cubic foot ; to reduce it to 73 per cent., or 5.5 grains per cubic foot, while the external air contained 5.2, we should have $\frac{5.8-5.5}{5.5-5.2} = \frac{0.3}{0.3} = 1$, or we should require to add to the existing delivery of air, at least as much more per hour as would equal the total cubic space. In the case referred to this was about 2256 cubic feet. The actual supply was 2080, total 4335 per head, or about the quantity demanded for proper hospital ventilation.

SECTION II.

THE MODE IN WHICH THE NECESSARY QUANTITY OF FRESH AIR CAN BE SUPPLIED.

This is an engineering problem, and there can be no doubt that in time to come it will be as carefully considered by engineers as the supply of water, or the removal of the solid and fluid excreta. Ventilation is, in fact, the problem of the removal of the gasiform excreta of the lungs and skin.

Sub-Section I.—Preliminary Considerations.

1. *Cubic Space.*[1]—A certain amount of fresh air has to pass through a given air-space in a fixed time in order to maintain a certain degree of purity; the amount has been fixed at 3,000 cubic feet for each healthy person in an hour; before considering the appliances for moving this air, we must consider what should be the minimum size of the air-space through which the fresh air has to pass.

This will entirely depend on the rate at which air can be taken through the space without the movement being perceptible or injurious. The size of the space is of consequence, chiefly, in so far as it affects this condition. The larger the air-space the less is the necessity for the frequent renewal of air, and the less the chances of draught. Thus a space of 100 cubic feet must have its air changed thirty times in an hour, if 3,000 cubic feet of air are to be given, while a space of 1,000 cubic feet need only have it changed three times in an hour for an equal ventilation.

When the most perfect mechanical means are employed, the air of even a small air-space can be changed sufficiently often without draught. Thus, in Pettenkofer's experimental room at Munich, the air-space is 424 cubic feet, and 2,640 cubic feet can be drawn through by a steam engine in an hour without perceptible movement; in other words, the change is six times per hour nearly. With the best mechanical contrivances, and with disregard of cost, we are therefore certain that a cubic space of 600 feet would be sufficient, and there is every probability that engineers could ventilate even a smaller space without perceptible movement.

But if the mechanical contrivances are of an inferior kind, and particularly if natural ventilation is used, the difficulties of ventilating a small space are considerable, and are caused not so much by the rate of movement of the greater part of the air in the room, as by the rate at the openings where the fresh air comes in very quickly, and causes currents in the room. Suppose, for example, a space of 500 cubic feet with a man

[1] In the metropolitan lodging-houses, 30 superficial and 240 cubic feet are allowed; in the section-houses of the metropolitan police 50 superficial and 450 cubic feet are given. The Poor-law Board allows 300 cubit feet for every healthy person in dormitories, and from 850 cubic feet and upward, according to circumstances, as far as 1,200 cubic feet for every sick person. In Dublin, an allowance of 300 cubic feet is required in the registered lodging-houses.—(From an excellent pamphlet, entitled Essentials of a Healthy Dwelling, p. 13.) In the Prussian army the allowance is 495 cubic feet (Prussian measurement, which is nearly the same as English), the superficial space being 42–45 square feet; in the old Hanoverian army the cubic space was 700 to 800 cubic feet (Prussian). The London School Board have given, in a general schoolroom, 10 square feet per scholar, and in graded schools 9 square feet; the height was ordered to be 13 feet—making 130 and 117 cubic feet respectively. This seems very small.

in it, who has to be supplied with 3,000 cubic feet in an hour; if the inlet opening be 12 square inches, the rate of movement through it would be 10 feet per second, or nearly 7 miles per hour; if 24 square inches, it would be five feet, or about 3.4 miles per hour. In either case, in such a small room, the air could not be properly distributed before reaching the person, and a draught would be felt. If instead of 500 cubic feet 1,000 be given, the problem is easier, for the small current of fresh air mixing with the larger volume of air in the room is more easily broken up, and the man being further from the opening, the movement is less felt. The question, in fact, turns in great measure on the power of introducing the air without draught.

If the renewal of air is carried on by what is termed natural ventilation, under the ordinary conditions of this climate, a change at the rate of six times per hour, as in Pettenkofer's room, could not be attempted. Even five times per hour would be too much; for, in barracks with 600 cubic feet per head, the rooms are cold and draughty, when anything approaching to 3,000 cubic feet per head per hour are passing through; that is a change of five times per hour for each 600 cubic feet of air-space. A change equal to three times per hour is generally all that can be borne under the conditions of warming in this country, or that is practically attainable, and if this be correct, from 1,000 to 1,200 cubic feet should be the minimum allowance of the initial air-space.

With good warming and an equable movement, which, however, is not always easy to get, there might be larger inlets and therefore more easy distribution and a smaller air-space to begin with. If the inlets are 48 square inches, the rate through them to supply a space of 500 cubic feet with 3,000 cubic feet per hour would be only 2½ feet per second; and if, as should be the case in artificial ventilation, the inlet is 72 or 80 square inches in size, the rate would only be a little over 1½ foot per second, which would be imperceptible even at the orifice. But there is an argument against a small cubic space, even with good mechanical ventilation, viz., that if anything arrests the mechanism for a time, the ratio of impurity from respiration increases much faster in a small than in a large space.[1]

The warmth of the moving air influences the sensation of the persons exposed to it. At a temperature of 55° or 60°, a rate of 1½ foot per second (=1 mile per hour nearly) is not perceived; a rate of 2 to 2½ per second (1.4 and 1.7 miles per hour) is imperceptible to some persons; 3 feet per second (2 miles per hour nearly) is perceptible to most; a rate of 3½ feet is perceived by all persons; any greater speed than this will give the sensation of draught, especially if the entering air be of a different temperature, or moist. If the air be about 70° Fahr., a rather greater velocity is not per-

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[1] Experimental data on many of these points are still wanting. In prisons, with cells for separate confinement and artificial ventilation, the amount of space is seldom under 750 to 800 cubic feet, and practically this is found to be too small.

In Pentonville Prison, on Jebb's system, the air was hardly ever changed three times in the hour, during my experiments, although the cells are nearly 800 feet in capacity. The mean supply of air per hour was about 1,056 cubic feet. In Gosport military prison, also on Jebb's principle (but not perfectly carried out), the mean supply was about 800 cubic feet, but the cells are only about 600 in capacity. In Aldershot military prison (not on Jebb's principle) with cells about 600 cubic feet in size, the mean supply was under 500. And in Chatham convict prison, where the cells are only 200, the mean supply was about 480. Wilson (Hand-book of Hygiene) appears to have found the air changed in the large cells at Portsmouth convict prison about three times in the hour, and in the small about four times; this, however, is certainly not the rule.—(F. de C.)

ceived, while if it be still higher (80° to 90° Fahr.), the movement becomes again more perceptible, and this is also the case if the temperature be below 40° Fahr. If the air could be warmed to a certain point in a cold climate, or if the climate be warm, there may be a much more rapid current, and consequently a smaller cubic space might be given. The subject of ventilation is in cold climates connected inseparably with that of warming, for it is impossible to have efficient ventilation in cold weather without warming the air.

The amount of cubic space thus assigned for healthy persons is far more than most people are able to have; in the crowded rooms of the artisan class, the average entire space would probably be more often 200 or 250 cubic feet per head than 1,000. The expense of the larger rooms would, it may be feared, be fatal to the chance of such an ideal standard being generally carried out; but, after all, the question is, not what is likely to be done, but what ought to be done; and it is an encouraging fact that in most things in this world, when a right course is recognized, it is somehow or other eventually carried out.

So, in the case of soldiers, the amount of authorized regulation space (600 cubic feet), is below the standard now given, but still the space is as much as can be demanded at present, as it has been found very difficult, without incurring greater expense than the country would bear, to give every man even the 600 cubic feet.

For sick persons the cubic space should be more than for healthy persons. We are to remember that there are other impurities besides those arising from respiration and transpiration, and that immediate dilution and as speedy removal as can be managed are essential.

Very much the same considerations apply to sick as to healthy men, except that the allowance of air in all cases of acute diseases must be greater; and, therefore, especially if natural ventilation be employed, the cubic space has to be enlarged also, to insure good distribution without draught, for surface chilling must be carefully avoided.

Admitting that, in hospitals, a minimum of 4,000 cubic feet of fresh air per patient per hour should be supplied, if the change of air is to be three times per hour, as the best available rate of movement, the cubic space must be about 1,300 cubic feet. A consideration of another kind may aid in determining the question as regards sick men. In hospitals a certain amount of floor-space is indispensably necessary; first, for the lateral separation of patients; secondly, for convenience of attendance. For the first object, the greater floor-space the better; and in respect of the second, Dr. Acland has clearly shown that the *minimum* floor-space for convenient nursing should be 72 square feet per bed.[1] In a ward of 12 feet in height this would give only 864 cubic feet, which is much too small.

Considering, however, the immense benefit to patients of pure air, and the practical experience of hospital physicians, it is very desirable not to fix the floor and cubic space of hospital wards at the minimum of what may suffice. The desire of most hospital physicians and surgeons is to obtain for their patients, if they can, a floor-space of 100 to 120 square feet, and a cubic space of 1,500 to 2,000 cubic feet, and in this they are right.

It must be distinctly understood that a minimum of floor-space must be insisted upon in all cases, not less than $\frac{1}{12}$ of the cubic space.[2]

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[1] See Report of the Committee appointed to inquire into the cubic space of Metropolitan Workhouses, 1867, p. 12.

[2] On this subject see further in Vol. II., chapter on HABITATIONS.

A notion prevails among many people, that cubic space may take the place of change of air,—so that if a larger cubic space be given, a certain amount of change of air may be dispensed with, or less fresh air be required. This is quite erroneous: even the largest space can only provide sufficient air for a limited time, after which the same amount of fresh air must be supplied hourly, whether the space be large or small. This is shown by the table on page 149, and may also be mathematically demonstrated by the formula given below.[1] Even in a space of 10,000 cubic feet per head the limit of admissible impurity would be reached in a little over 3 hours, after which the same hourly supply of 3,000 feet would be as necessary as in a space of 100 cubic feet.[2]

Cubic Space required for Animals.

The amount of cubic space for animals has not been very carefully examined. If we followed the rule for men and gave one third of the quantity of air supplied per hour, this would give for horses and cattle from 3,000 to 7,000 cubic feet. This, however, is probably not necessary, because change of air can be carried on more freely than in human habitations, and animals cannot close ventilators as men will often do. A floor-space of 100 to 120 square feet would probably be sufficient, giving a space of 1,200 to 1,800 cubic feet, according to the height of the building. If this could be secured there is every probability that the results would be excellent. We might put the estimate roughly at 2 cubic feet of space for every lb avds. the animal weighs,—the floor-space being not less than $\frac{1}{12}$ of the cubic capacity.

At present, the Army Regulations allow, in new stables, each horse 1,605 cubic feet, and 100 square feet of floor-space;[3] and the means of ventilation, as will be presently noticed, are ample.[4] In the Army Horse Infirmaries, the superficial area is to be 137 square feet, and the cubic space 1,900 feet per horse.

In the stables of cattle there is often excessive over-crowding, and it is well known that there is a vast amount of disease among them, which, however, is seldom allowed to go far, as they are sent to the butcher. Dr. Ballard, who paid great attention to the cattle plague in Islington, recommended that at least 1,000 cubic feet should be allowed per animal.

2. *Source of the Air supplied.*—In order that the object of the ventilation shall not be defeated, it is necessary that the air entering a room

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[1] $\rho_1 = \frac{e}{d}\left(1 - \epsilon^{-\frac{dh}{c}}\right)$, where ρ_1 = ratio of respiratory impurity at the time (h), (ϵ) the amount of impurity involved during (h), (d) the supply of fresh air, (ϵ) the exponential function, viz., 2.718, and (c) the capacity of the air space. Soon after the first hour the coefficient $\epsilon^{-\frac{dh}{c}}$ practically vanishes, and with it vanishes also the small influence the cubic space exercises.

[2] For further remarks on this point, see my Lectures on State Medicine; also "Hygiene" in Sanitary Record, 1874–75. In a pamphlet by General Morin, Note sur l' espace cubique, etc., a table is given that might be misleading, without explanation. It really shows the amount of air necessary to dilute a certain amount of impurity evolved in a certain cubic space, and is similar to the table given on page 159 of this work. For continuous ventilation the necessary supply in any ordinary space of the first hour, is a constant quantity. This can be shown by asymptote lines also. See paper by C. Herscher, Société de Médecine Publique, in Revue d'Hygiène, vol. iii., p. 207.—(F. de C.)

[3] Report of the Barrack and Hospital Improvement Commission on the Ventilation of Cavalry Stables, 1866, p. 10.

[4] See Book II., Vol. II.

shall be pure. The air must be the pure external air, and not be derived from places where it has stagnated and taken up impurities ; if it is drawn along passages or tubes, and through louvres or basements, these should be capable of inspection and cleansing. All air-shafts should, if possible, be short and easily cleaned. This is an important rule, and should lead to the rejection of all plans in which the air-shafts are long and inaccessible. Several instances have occurred of air being distributed by costly appliances, but drawn from an impure source, or allowed to be contaminated on its passage. Instead of perforated bricks, there should be sliding panels, or hinged flaps, so that the tube may be easily reached. In towns it may be necessary to filter the air, which is often loaded with the products of combustion and other impurities.

3. *Warming or Cooling of the Air.*—The air may require to be warmed to 60° or 65° Fahr., or cooled according to the season or locality. The warming in cold and temperate climates is a matter of necessity, as, if discomfort is caused by cold draughts, ventilation openings are certain to be closed.

4. *Distribution.*—The distribution in the rooms should be perfect, that is, there should be uniform diffusion of the fresh air through the rooms. The best way of ascertaining this is to compare the amount of air utilized, as calculated from the observed CO_2, with the actual movement of air, as measured with the air-meter. If the distribution is good, the two quantities ought not to differ materially. Much difficulty is found in properly managing uniform diffusion, and it requires careful arrangement of the various openings. The distributing plans should, if possible, prevent the chance of breathed air being rebreathed, especially in hospitals. As the ascent of respired air is rapid, on account not only of its temperature, but from the force with which it is propelled upward, the point of discharge for patients in bed should be above.

By some it has been argued that it is better that the foul air should pass off below the level of the person, so that the products of respiration may be immediately drawn down below the mouth, and be replaced by descending pure air. But the resistance to be overcome in drawing down the hot air of respiration is so great that there is a considerable waste of power, and the obstacle to the discharge is sometimes sufficient, if the extracting force be at all lessened, to reverse the movement, and the fresh air forces its way in through the pipes intended for discharge. This plan, in fact, must be considered a mistake. The true principle is that stated long ago by D'Arcet. In the case of vapors or gases the proper place of discharge is above ; but heavy powders, arising in certain arts or trades, and which from their weight rapidly fall, are best drawn out from below.

Sub-Section II.—Means by which Air is set in Motion.

These are :—1st, the forces continually acting in nature, which produce what has been termed natural ventilation. 2d, the forces set in action by man, which produce the so-called artificial ventilation.

The division is convenient, but not strictly logical, as the forces which act in natural do so also in artificial ventilation to a certain extent.

Natural Ventilation—General Statements.

Three forces act in natural ventilation, viz., diffusion, winds, and the difference in weight of masses of air of unequal temperature.

1. DIFFUSION.

As every gas diffuses at a certain rate, viz., inversely as the square root of its density, there is a constant escape of any foreign gas into the atmosphere at large. From every room that is not air-tight Pettenkofer and Roscoe have shown that diffusion occurs through brick and stone, and Pettenkofer believes that one of the evils of a newly built and damp house is that diffusion cannot occur through its walls. But the ordinary plastered and papered walls reduce diffusion to a most insignificant amount. Through chinks and openings produced by imperfect carpentry the air diffuses fast, and Roscoe found that when he evolved carbonic acid in a room the amount had decreased one-half from that cause in 90 minutes.

The amount of purification produced by diffusion under ordinary circumstances is shown by observation to be insufficient ; and, in addition, organic substances, which are not gaseous, but molecular, are not affected by it. As a general ventilating power, it is therefore inadequate.

2. THE ACTION OF THE WINDS.

The wind acts as a powerful ventilating agent, and in various ways. If it can pass freely through a room, with open doors and windows, the effect it produces is immense. For example, air moving only at the rate of 2 miles an hour (which is almost imperceptible), and allowed to pass freely through a space 20 feet wide, will change the air of the space 528 times in one hour. No such powerful action as this can be obtained in any other way.

The wind will pass through walls of wood (single-cased), and even of porous bricks or stone ; and perhaps this will account for the fact that such houses, though cold, are healthy habitations. By covering a brick with wax, or inclosing a portion of a brick wall in an air-tight box, Pettenkofer has shown that the force of the breath will drive air through the brick and will blow out a candle on the other side if the current of air be collected in a small channel. The force required to drive the air through is, however, really considerable, as the air in the brick must be brought into a state of tension.

Märcker [1] has given the following as the amount of air passing in one hour through a square metre of wall space, when the difference of temperature is 1° C. :—Sandstone, 1.69 ; limestone, 2.32 ; brick, 2.83 ; tufaceous limestone, 3.64 ; and loamy brick, 5.12 cubic metres of air. The little porosity of sandstone depends on the amount of moisture it holds. The moisture, in fact, greatly influences the transit. Plaster, however, appears to arrest wind, if it be true, as stated, that in the interior of some thick walls, after many years, lime has been found still caustic ; and Märcker also notices the obstructive effects of mortar.

There are two objections to winds as ventilating agents by perflation.

(1) The air may be stagnant. In this country, and, indeed, in most countries, even comparative quiescence of the air for more than a few hours is scarcely known. Air is called " still " when it is really moving 1 or $1\frac{1}{2}$ mile an hour. The average annual movement of the air in this country is from 6 to 12 miles per hour ; but it varies, of course, greatly from day to day, and in different places. The mean movement at Netley (average of

[1] Untersuch. über nat. et künstliche Ventilation. Göttingen, 1871.

13 years) is about $10\frac{1}{3}$ miles per hour; at Aldershot it is $12\frac{1}{2}$ miles per hour (mean of 5 years).

(2) A much more serious evil is the uncertainty of the movement, and the difficulty of regulation. When the velocity reaches 5 or 6 feet per second, unless the air be warm, no one will bear it. The wind is therefore excluded, or, if allowed to enter directly through small openings, is badly distributed. Passing in with a great velocity, it forces its way like a foreign body through the air in the room, causing draughts, and escaping, it may be, by some opening without proper mixing. A current entering in this way may be measured for many feet.

But the wind acts in another way. A moving body of air sets in motion all air in its vicinity. It drives air before it, and, at the same time, causes a partial vacuum on either side of its own path, toward which all the air in the vicinity flows at angles more or less approaching right angles. In this way a small current moving at a high velocity will set in motion a large body of air.

The wind, therefore, blowing over the tops of chimneys, causes a current at right angles to itself up the chimney, and the unequal draught in furnaces is owing, in part, to the variation in the velocity of the wind. Advantage, therefore, can be taken of this aspirating power of the wind, to cause a movement of air up a tube. The wind, however, may impede ventilation by obstructing the exit of air from any particular opening, or by blowing down a chimney or tube. This is, in fact, one reason of the failure of so many systems of ventilation; they may work well in a still atmosphere, but the immense resistance of the wind has not been taken into account. At 3 miles an hour, the pressure of the wind is $\frac{3}{4}$ of an ounce on each square foot; it is 1 ounce at $3\frac{1}{2}$ miles; 2 ounces at 5 miles; 4 ounces at 7 miles; $\frac{1}{2}$ ℔ at 10 miles; and 1 ℔ at 14 miles. At Netley the average pressure is a little over $\frac{1}{2}$ ℔ per square foot.

In some systems of ventilation the perflating power of the wind has been used as the chief motive agent. In Egypt the wind is allowed to blow in at the top of the house through large funnels. This plan has been in use from time immemorial. This was the case in Mr. Sylvester's plan, which was used at Derby and Leicester fifty or sixty years ago. A large cowl, turning toward the wind, was placed in a convenient spot near the building to be ventilated—a little above the ground if in the country, or at some height if in a town. The wind blowing down the cowl, passed through an under-ground channel to the basement of the house, and entered a chamber in which was a so-called cockle-stove or calorifere of metal plates or water or steam pipes, by which the air was warmed. It then ascended through tubes into the rooms above, and passed out by a tube or tubes in the roof, which were covered by cowls turning from the wind. So that the aspiratory power of the air was also used. This plan is extremely economical, but the movement of the air is unequal, and it is difficult to regulate it. It has been proposed to place a fan in the tunnel to move the air in periods of calm, and the plan then becomes identical in principle, and almost in detail, with the method of Van Hecke.

Mr. Ritchie [1] has employed a similar plan in the ventilation of a dwelling-house. The air is warmed in winter to about 70° Fahr.; every room has a longitudinal opening over each door, concealed by the architrave, and regulated by valves, and through this the warm air from the staircase enters the rooms, and then passes up the chimney, and up outlet air-flues

[1] Treatise on Ventilation, by Robert Ritchie, C.E., 1862, p. 89.

placed in the walls, commencing at the ceiling, and ending at the wall-heads under the roof.

Dr. Arnott ventilated the Field Lane Ragged School on this principle with excellent effect. In that case, as in all others, the movement was also in part carried on by the third cause of motion in air, viz., the effect of unequal density of masses of air.

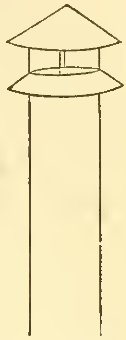

Fig. 12.—Diagram of Fixed Upcast Cowl.

In the ventilation of ships, the wind is constantly used; and by windsails and tubes with cowls turning toward the wind, air is driven between the decks and into the hold.

In using the wind in this way, the difficulty is to distribute the air so that it shall not cause draughts. This is best done by bending the tubes at right angles two or three times, so as to lessen the velocity, by enlarging the channel toward the opening in the interior of the vessel, and by placing valves to partially close the tubes, if necessary, and by screens of wire gauze.[1]

In all cases in which the air of a room, as in a basement story, or in the hold of a ship, perhaps, is likely to be *colder* than the external air, and when artificial means of ventilation cannot be employed, the wind should be taken advantage of as motive agent.

The aspiratory power of the wind can be secured by covering air-shafts with cowls such as that shown in Fig. 12, which aid up currents and prevent down draughts.

3. MOVEMENTS PRODUCED BY UNEQUAL WEIGHTS OF AIR.

The wind itself is caused by this power; but it is necessary, in discussing ventilation, to look upon this as if it were an independent force. If the air in a room be heated by fire, or the presence of men or animals, or be made moister, it endeavors to expand; and if there be any means for it to escape, a portion of it will do so, and that which remains will be lighter than an equal bulk of the colder air outside. The outer air will then rush into the room by every orifice, until the equality of weight outside and inside is re-established. But as the fresh air which comes in is in its turn heated, the movement is kept up in a constant stream, cold air entering by one set of orifices, and hot air escaping by another.

We have now to inquire how the rate of this constant stream of air may be calculated.[2] The mode most generally used is based on two well-known laws:—first, that the velocity in feet per second of falling bodies is equal to (nearly) 8 times the square root of the height through which they have fallen; and, second, that fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the

[1] As the use of perforated zinc plates and of wire-gauze is very common in ventilation, it is necessary to bear in mind that these screens very soon get clogged with dirt. In all cases they should be so arranged as to be easily inspected and cleaned; and it should be a matter of routine duty to see that they are constantly kept clean. It should also be understood that the delay by friction through the fine wire-gauze is exceedingly great.

[2] Many of these points are given in Hood's Treatise on Warming and Ventilation, and in Wolpert (Principien der Vent. und Luftheizung), and are also discussed in Péclet (Traité de la Chaleur, third edit.), and by General Morin (Études sur la Ventilation, Paris, 1863, t. ii.), to which reference is made for those who wish to enter into the mathematical part of the inquiry.

partition.[1] The pressure of air upon any surface may be represented by the weight of a column of air of uniform density of a certain height. Thus the pressure of the atmosphere at the surface of the earth is nearly 15 lb on the square inch, and this would be the weight of a column of air of about 5 miles in height. Air, therefore, rushes into a vacuum with a velocity equal to that which a heavy body would acquire in falling from a height of 5 miles, viz., 1,304 feet per second. But if, instead of rushing into a vacuum, it rush into a chamber in which the air has less pressure than outside, its velocity will be that due to a height which represents the difference of pressure outside and inside. In ordinary cases this difference of pressure cannot be obtained by direct observation, but must be inferred from the difference of temperature of the outer and inner air. Air is dilated one part in 491 of its volume for every degree of Fahrenheit (or 1 in 273 for every degree of centigrade) that its temperature is raised, consequently the difference of pressure outside and inside will be as follows:—

The height from the aperture at which air enters to that from which it escapes, multiplied by the difference of temperature between outside and inside, and divided by 491.

If the height be 20 feet, and the difference of temperature 15 degrees, we have the height to produce velocity of inflowing current $= \frac{20 \times 15}{491} = 0.61$ of a foot, and the velocity $= 8\sqrt{.61} = 8 \times .781 = 6.248$. This, however, is the theoretical velocity. In practice an allowance must be made for friction of $\frac{1}{4}$th, $\frac{1}{3}$d, or even $\frac{1}{2}$, according to circumstances. The deduction of $\frac{1}{4}$th would leave 4.686 linear feet per second as the actual velocity. If this be multiplied by the area of the opening, in feet, or decimals of a foot,[2] the amount of air is expressed in cubic feet per second, and multiplying by 60 will give the amount per minute.

A table is given at page 194, in which this calculation has been made for all probable temperatures and heights; but it must be remembered that the movement is greatly influenced by the wind.

This cause of movement is, of course, constantly acting when the temperature of the air changes. It will alone suffice to ventilate all rooms in which the air is hotter than the external air, but will not answer when the air to be changed is equal in temperature to, or colder than, the external air.

As its action is equable, imperceptible, and continuous, it is the most useful agency in natural ventilation in cold climates, in inhabited and warm rooms; and in all habitations arrangements should be made to allow it to act. As the action increases with the difference of temperature, it is most powerful in winter, when rooms are artificially warmed, and is least so, or is quite arrested in summer, or in hot climates, when the internal and external temperatures are identical.

4. LOSSES PRODUCED BY FRICTION FROM VARIOUS CAUSES.

This aspect of the question has hardly received the attention it deserves, and its neglect is apt to lead to failure and disappointment. The chief causes of loss are the following:—

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[1] This is frequently called the rule of Montgolfier. The formula is $v = \sqrt{2gH}$; g being the acceleration of velocity in each second of time, viz., 32.18 feet, and H the height of the descent.

[2] It will be found always easier to take the area in decimals of a foot instead of inches; but if it be taken in inches, multiply the linear discharge by the number of square inches, and divide by 144.

1. *Length of Tube or Shaft.*—Here with equal sectional areas the loss is directly as the length, so that if we take a shaft of 30 feet as a standard, a shaft of 40 feet long would have an increased friction of one-third.

2. *Size of Opening.*—For similar sections the friction is inversely as the diameter. Thus for two openings, respectively 1 and 2 feet in diameter, the friction at the smaller opening will be twice that of the larger. In this way dividing up an opening into a number of smaller openings, the aggregate of which is equal to the original opening, produces a loss by friction in the direct ratio of the diameters. An opening of 1 square foot divided into four openings of $\frac{1}{4}$ of a square foot loses in the ratio of $1 : \frac{1}{2}$, being respectively the diameters of the openings. When the shapes of the openings are not similar, the ratio may be stated as that of the square roots of the areas. Thus 1 square foot divided into nine openings, each equal to $\frac{1}{9}$ of a square foot, will lose in the ratio of $1 : \frac{1}{3}$, the square roots of the respective areas.[1]

3. *Shape of Opening.*—A circular opening may be taken as the standard, that being the figure which includes the greatest area within the smallest periphery. The loss sustained from any other shape being used will be proportionate to its difference from a circle enclosing a similar area. Thus, if we have two openings, each of 1 square foot area, the one being a circle and the other a square, the length of periphery of the latter will be 4 square feet, of the former $3\frac{1}{2}$; therefore the velocity of the current through the square opening will be $\frac{3\frac{1}{2}}{4}$ or $\frac{7}{8}$ of that through the circular opening.[2]

4. *Angles in the Tube or Shaft.*—This is a most serious cause of loss. The exact formula has not been distinctly determined, but it may be accepted, as in accordance with experiment, that every right angle diminishes the current by one-half, so that two right angles in a tube would reduce it to $\frac{1}{4}$, and so on.[3] Yet it is no uncommon thing to find tubes and shafts bent recklessly at numerous angles to fit a cornice or architrave, to save expense and appearance.

5. The presence of dust, soot, or dirt of any kind seriously interferes with the current, but this may of course be obviated with a moderate amount of care and attention.

It is obvious that attention to the above points is necessary to obtain success in any scheme of ventilation. To take an example; let us suppose a straight shaft 30 feet long, sectional area circular, of 1 square foot,—the current through this giving a sufficient amount of air for the purpose required. Let it be necessary to produce a similar amount of ventilation in another place, but to use smaller shafts, square in section, area of each $\frac{1}{4}$ of a square foot,—each shaft being 40 feet long, and having one right angle in its course; what would be the relative amounts of air available, other things being equal? Taking the circular shaft, we have length of shaft 30, length of periphery $3\frac{1}{2}$, total $33\frac{1}{2}$ = friction. In the four smaller shafts we have length 40, length of periphery of each 2, which multiplied by $4 = 8$, total 48: the right angle doubles the friction, so that

[1] See General Morin's Observations.

[2] For a table of friction due to form of sectional area, see "Hygiène," in Sanitary Record, 1875, by Dr. F. de Chaumont.

[3] The formula $\frac{1}{1 + \sin^2\theta}$ expresses the condition approximately between 0° and 90°; but $\frac{1 + \cos\theta}{2}$ is of more general application, including any angle between 0° and 180°. In either case 90° shows a loss of *one-half*.

48 × 2 = 96 as compared to 33½. Thus the result would be nearly as 3 to 1 in favor of the single shaft. It would be obviously necessary to treble either the number of the smaller shafts or the size of each of them.

It is advisable generally to widen slightly the openings of shafts, especially if they are of small diameter, as the current tends to be contracted and obstructed at that point. At every change of direction the same thing takes place. Hence the desirability of rounding off angles as much as possible, where they cannot be altogether avoided.[1]

It is generally best to have the sections of shafts circular or elliptical instead of rectangular, for not only is there less loss by friction originally, but there is less chance of lodgement of dust, etc., and they can be more easily and thoroughly cleaned.

5. PRACTICAL APPLICATION OF THE GENERAL STATEMENTS OF NATURAL VENTILATION.[2]

1. No particular arrangements are necessary to allow diffusion to act, except that there shall be communication between two atmospheres.

2. To obtain the perflation of the wind, windows should be placed, in all cases where it can be managed, at opposite sides of a room. The windows should open at the top, and in case the wind has a high velocity, means should be taken to distribute it. This can be done by sloping the window inward when it opens, or a board may be placed obliquely upward from the top sash of the window, when it opens in the usual way ; then the air striking against the board is thrown up toward the ceiling. Or, wire-gauze may cover the space left when the window is open. The velocity of the wind is checked by the gauze, and the current is minutely divided. The gauze, however, must be kept clean.

Various plans have been proposed by different persons. The panes of glass may be made double, spaces being left at the *bottom* of the outside pane and at the *top* of the inner one, so that the wind is obliged to pass up between the two panes before it enters the room. Or, the lower sash being raised, and a piece of wood placed below it, the air is allowed to pass through the space left between the upper and lower sashes (Hinckes Bird). Or, glass louvres, which can be more or less closed, are placed in one of the panes of the window ; or a number of holes are obliquely bored through the panes, through which the air may pass up toward the ceiling before it intermixes with the air of the room. In Lockhead's ventilator there is a frame over the glass louvre, with a regulator in the centre. In Cooper's ventilator a movable plate of glass can be brought by a movable handle over the opening.

Stallard has proposed to ventilate workshops and factories by having a double ceiling ; the lower ceiling is to be made of zinc or oiled paper, perforated with very numerous small holes ; and the space between the two ceilings is to be freely open to the air on all sides ; thus there would be almost open-air breathing, as the communication with the external air would be constant and at all parts of the room.

Besides windows, special openings may be provided for the wind to

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[1] On this question see Wolpert, Theorie u. Praxis der Ventilation u. Heizung (1879), p. 210 et seq.

[2] A very good account of the various plans in natural ventilation will be found in Mr. Edward's work, On the Ventilation of Dwelling-Houses, 1868, in which figures of the plans are given ; see also Eassie, "Dictionary of Sanitary Appliances," Sanitary Record, 1880–82.

blow through, as in the plans already referred to of Mr. Sylvester and Dr. Arnott.

In all warm climates, where no chill can be produced by wind, it is a good plan to make the walls entirely pervious. Nothing can be better than the ventilation of the bamboo matted houses in Burmah. The wind blows through them, but it is so broken up into currents that it is not in the least unpleasant. Even in colder parts of India, the upper parts of the walls might be made thus pervious, provision being made to cover them, if necessary, in the cold season.

Cowls have been a good deal recommended as aids to ventilation, but the labors of the Committee of the Sanitary Institute of Great Britain, though not yet completed, have shown that the majority of them have no superiority over the open tube. The only form which seemed fairly good was the common *lobster-backed* cowl. For general use, however, this would require to revolve, and this is objectionable, as all revolving arrangements are liable to get out of order. A fixed cowl, consisting merely of a cone as a cap and a similar flange round the rim of the pipe, insures a fairly constant up draught (Fig. 12). A reversed arrangement (Fig. 13) insures a constant down draught.

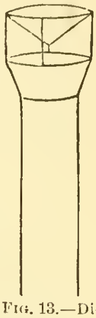

Fig. 13.—Diagram of a fixed *downcast* tube, with trumpet mouth and inverted conical cap.

Another plan for utilizing the action of the wind is by the use of "Ellison's conical bricks," which are pierced with conical holes, about $\frac{2}{10}$ of an inch diameter externally and $1\frac{1}{4}$ in. internally, depth $4\frac{1}{2}$ in. The wind blowing on them is so distributed as to be imperceptible as a draught in the room.

3. The movement produced by the difference of weight of unequally heated bodies of air will, of course, go on through open windows and doors and through all the contrivances just mentioned. But as in cold climates windows and doors must sometimes be shut, no room of any kind should be without additional openings, which may permit this movement from unequal temperature to go on. The great difficulty here is to exclude the action of the wind; and, in fact, it is impossible to do so; but, as far as possible, the openings should be protected from the perflating influence of the wind, so that only its aspirating force should be acting. They should be capable of being lessened in size, when the difference of the external and internal temperatures is great. As long as there are openings, movement will go on; and it does not really matter, as long as there is proper distribution, where the air comes in or goes out, or whether its direction is constant. In fact, it scarcely ever is constant, so liable is the direction to be altered by winds, by the action of the sun heating one side of a room, by the unequal distribution of heat in the room, etc. Still it seems desirable, as far as it can be done, to make such arrangements as shall give the movement of air a certain direction; and therefore, in most systems, some of the openings are intended for the admission of fresh air, and are called *inlet, entrance*, or *adduction* openings; others are intended for the discharge of impure air—and are termed *outlet, exit*, or *abduction* openings.

Total size of all the Special Openings, whether intended for Inlets or Outlets.—As the movement of air increases with temperature, the size of the apertures can only be fixed for a certain given temperature; and as the efflux of hot air increases with the height of the column (supposing the temperature is equal throughout), a different size has also to be fixed for different heights.

This causes a difficulty in fixing the proper size for ventilating openings

in the case of natural ventilation, as the conditions are so variable. The theoretical size for any required change of air, supposing the conditions were constant, may be obtained from the table at page 194, which is calculated from Montgolfier's formula, with a deduction of $\frac{1}{4}$th for friction.

Thus, say that the height of the heated column is 20 feet, and the difference of temperature between the air in the room and that outside is 20° F., the linear rate of discharge as stated by the table (allowance being made for friction) is 322 feet per minute, or 19,320 feet per hour. If the opening were 1 square foot this would give 19,320 cubic feet per hour. But if 3,000 cubic feet per hour are wanted for one person, the orifice of 1 square foot, or 144 square inches, is too large, and must be lessened in the proportion of 3,000 to 19,320 $\frac{3000 \times 144}{19,320} = 22$ square inches (round numbers), *i.e.*, reduced to 22 square inches. There must be a corresponding space for entry, making the total ventilating opening 44 square inches.

To take another example; let us say the heated column is 15 feet, the difference of temperature 10° F., and the required supply for one person 2,000 cubic feet. The table gives the linear rate as 197 feet per minute, or 11,820 per hour; an orifice of 144 square inches would then give 11,820, and an orifice of 24 square inches would give 2,000; $\left(\frac{2,000 \times 144}{11,820} = 24\right)$. But if in the above conditions 3,000 cubic feet hourly supply were wanted, the opening must be 36 square inches. These examples show how impossible it is to fix any size which shall meet all conditions, even if the influence of wind could be completely excluded, which is impossible. The only way is to adopt a size which will meet most cases, and supply means of altering the size according to circumstances. In this country, a size of 24 square inches per head for inlet, and the same for outlet, seems calculated to meet common conditions; but arrangements should be made for enabling this to be lessened or closed in very cold weather, or if the influence of strong winds is too much felt.[1] Moreover, the size must be in part dependent on

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[1] The following formula proposed by Dr. de Chaumont can be used instead of the table at page 194. It is based on Montgolfier's formula, with the discharge calculated for the hour and for square inches, instead of for the minute and the linear discharge, as in the table.

Let h be the height of the heated column of air; t its temperature; t' the temperature of the external air; .002 the ratio of expansion of air for each degree of Fahr.; 100 a constant; and f the coefficient of friction. Let D be the delivery required per hour, and Φ the total inlet and outlet area in square inches. Then to find Φ:

$$\frac{D}{100 f\left(\sqrt{h(t-t') + .002}\right)} = \Phi.$$

Example: Suppose, as in the text, that the heated column be 20 feet, its mean temperature 65°, and that of the outer air 45°, and the required delivery be 3,000 cubic feet per hour; let f also equal $\frac{3}{4}$ or .75.

$$\frac{3000}{100 \times .75\left(\sqrt{20(65^{\circ} - 45^{\circ}) \times .002}\right)} = 44.4$$

square inches for inlet or outlet, or 22.2 for inlet alone.

A converse formula by Dr. de Chaumont may be also useful. If the area of the inlet opening (Φ') is known, to find the delivery per hour under conditions h, t, and t'.

$$200 f\left(\sqrt{h(t-t') \times .002}\right)\Phi' = D.$$

The constant 200 is obtained by multiplying 3,600 (seconds per hour) by twice the square root of 16.09 (= 8 nearly), and dividing by 144 square inches. By halving this constant we get the number for both inlet and outlet together.

the size of the room, because in a small room with many people it is impossible to have the size so great as it would be if each person's area of ventilation opening were 48 square inches, unless some portion of the air were warmed.

Relative Size of the Inlets and Outlets.—It is commonly stated that, as the heated air expands, the outlets should be larger than the inlets, and the great disproportions of 5 to 4 and 10 to 9 have been given. As, however, the average difference of temperature is only about 10° to 15° Fahr. in this country, the disproportion is much too great, as a cubic foot of air only expands to 1.020361 cubic foot with an increase of 10°. Even if the difference is 30° Fahr., a cubic foot of air only becomes 1.061 cubic foot, which is equal to an increase of about $\frac{1}{17}$th. The difference is so slight that it may be neglected, and the inlets and outlets can be made of the same size.

It is desirable to make each individual inlet opening not larger than 48 to 60 square inches in area, or enough for two or three persons; and to make the outlet not more than 1 square foot, or enough for six persons. Distribution is more certain with these small openings.

Position and Description of the Inlet and Outlet Tubes.—1. *Inlets.*—The air must be taken from a pure source, and there must be no chance of any effluvia passing in. As a rule, the inlet tubes should be short, and so made as to be easily cleaned, otherwise dirt lodges, and the air becomes impure. Inlets should not be large and single, but rather numerous and small (from 48 to 60 inches superficial), so that the air may be properly distributed. They should be conical or trumpet-shaped where they enter the room, as the entering air, after perhaps a slight contraction, spreads out fan-like, and a slight back current from the room down the sides of the funnel facilitates the mixing of the entering air with that of the room. To lessen the risk of immediate down-draught they should turn upward, if they are placed above the heads of the persons. Externally the inlets should be partly protected from the wind; otherwise the wind blows through them too rapidly, and, if the current be strong, draughts are felt; an overhanging shelf or hood outside will answer pretty well. Valves must be provided to partially close the openings if the wind blows in too strongly, or if the change of air is too rapid in cold weather. If covered with wire-gauze, it must be frequently cleaned.

Sometimes an inlet tube must be carried some distance to an inner room, or to the opposite side of a large room which is unprovided with cross-ventilation. In this case the heat of the room so warms the tube that the wind may be permitted to blow through it.

The position of the inlets is a matter of some difficulty. If there are several, they should be, of course, equally distributed through the room, so as to insure proper mixing of the air. They should not, however, be placed too near an outlet, or the fresh air may at once escape; theoretically, their proper place of entrance is at the bottom of the room, but if so, the air must in this climate be warmed; no person can bear the cold air flowing to and chilling the feet. The air can be warmed easily in various ways, viz.:—

(*a*) The air may pass through boxes containing coils of hot-water pipes, or (in factories) of steam pipes. This is the best mode of warming. The coils may be close to the outside wall, or in the centre, or in hospitals in boxes under the beds communicating with the exterior air, and opening into the ward.

(*b*) The air may pass into air-chambers behind or round grates and stoves, and be there warmed, as in the present barrack and hospital grate,

contrived by Captain Galton ; or as in the Meissner or Böhm stoves of Germany ;[1] or as in the terra-cotta stove, in the Herbert Hospital at Woolwich.

(*c*) The air may be warmed in a tube passing through the stove, as in George's calorigen, or by the method of Bond's euthermic stove.

If the air cannot be warmed, it must not be admitted at the bottom of the room ; it must be let in above, about 9 or 10 feet from the floor, and be directed toward the ceiling, so that it may pass up and then fall and mix gradually with the air of the room. The Barrack Commissioners have adopted this plan with half the fresh air brought into a barrack-room. The other half is warmed. It answers fairly well.

In towns or manufacturing districts the air is so loaded with particles of coal, or, it may be, other powders, that it must be filtered. Nothing answers better for this than muslin or thin porous flannel, or paperhangers' canvas, spread over the opening, which then should be made larger. This covering can be moistened if the incoming air be too dry.

The tubes proposed by Mr. Tobin, of Leeds, provide for the introduction of air from the outside at the floor level and then up a vertical tube, about 4 feet in height ; this gives a vertical direction to the current, which is retained for several feet further before it begins to spread and descend. The action of such a tube is, of course, much affected by the direction of the wind, and in some instances it is reversed altogether. The method is, however, useful in some cases, particularly for introducing air into places which could only be reached with difficulty by other means. It has been tried on a large scale at St. Mary's Hospital, Paddington, with fair success.[2] In some forms (as made by the Sanitary Engineering Company), there is an arrangement for washing the air and arresting impurities. An ingenious contrivance for warming the air for the upright tube by means of a gas-jet has been suggested by Mr. Lawson Tait ; it also provides an outlet for foul air. A modification for bedrooms and other rooms in private houses is also recommended by Mr. Tobin, viz., to cut out slits between the sashes of the windows, so that the air enters vertically, even when the window is shut. This is similar in principle to other modifications of window ventilation already referred to, but it is only adapted for comparatively small rooms, and is quite inapplicable to a hospital ward or the like.

2. *Outlets.*—The place for the outlets is a most important consideration, as it will determine in great measure the position of the inlets. If there are no means of heating the air passing through them, they should be at the top of the room ; if there are means of heating them, they may be at any point. If not artificially warmed, the highest outlet tube is usually the point of greatest discharge, and sometimes the only one.

(*a*) *Outlet Tubes without Artificial Heat.*—They should be placed at the highest point of the room ; should be inclosed as far as possible within walls so as to prevent the air being cooled ; should be straight and with perfectly smooth internal surfaces, so that friction may be reduced to a minimum. In shape they may be round or square, and they may be covered above with some apparatus which may aid the aspirating power of the wind, and prevent the passage of rain into the shaft.

The causes of down-draught and down-gusts in outlet tubes are these :

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[1] The Germans appear to be now making great use of these ventilating stoves in hospitals, and even in private houses. For a good account, see Roth and Lex, loc. cit., p. 248 et seq.

[2] See Dr. de Chaumont's Report, op. cit.

the wind forces down the air, rain gets in, and, by evaporation, so cools the air that it becomes heavier than the air in the room ; or the air becomes too much cooled by passage through an exposed tube, so that it cannot overcome the weight of the superincumbent atmosphere ; or another outlet shaft, with greater discharge, reverses the current.

Arrangements should be made to distribute the down-draught, if it occurs ; flanges placed at some little distance below, so as to throw the air upward again before it mixes with the air of the room, or simple contrivances of a similar kind, may be used. Valves should be also fixed to lessen the area of the outlet when necessary. If there are several outlet tubes in a room, all should commence at the same distance from the floor, be of the same height (or the discharge will be unequal), and have the same exposure to sun and wind.

Simple ridge openings may be used in one-storied buildings with slanting roofs ; they ventilate most thoroughly, but snow sometimes drifts in. Rain may be prevented entering by carrying down the sides of the overhanging ridge for some little distance. A flange placed some little distance below will throw any down-draught toward the walls.

(*b*) *Outlets with Artificial Warmth.*—The discharge of outlets is much more certain and constant if the air can be warmed. The chimney with open fire is an excellent outlet—so good that in dwelling-houses, if there are proper inlets, no other outlet need be made, except when gas is used. When rooms are large, and more crowded, other outlets are necessary ; the heat of the fire may be further utilized by shafts round the chimney, opening at the top of the room, or, in other words, by surrounding the smoke-flue with foul-air shafts.

Gas, if used, should in all cases be made to warm an outlet tube, both to carry off the products of combustion, and to utilize its heat. The best arrangement appears to be to place over the gas-jet a pipe to carry off the products of combustion, and to case the pipe itself with a tube, the opening of which is at the ceiling ; the tube carrying off the gas products is hot enough to cause a very considerable draught in its casing, and thus two outlet currents are in action, one over the gas, and one from the ceiling round the gas-tube. A modification of the lamp proposed in 1846 by Mr. Rutter answers very well, and is in use, as arranged by Mr. Ricketts. A good form is also made by Messrs. Sugg.

In various other ways the heat of fire and lights may be taken advantage of.

There will seldom be any difficulty in arranging the inlets and outlets, and in obtaining a satisfactory result, if these principles are borne in mind, viz., to have the fresh air pure, to distribute it properly, and to adopt every means of securing the outlets from cold or of artificially warming them, and of distributing the air, which, in spite af all precautions, will occasionally pass down them.

In hot climates, when outlet shafts are run up above the general level of the building, it would be of advantage to make them of brick work, and to color them black, so that they may absorb and retain heat.

6. PLANS OF TUBES AND SHAFTS WHICH HAVE BEEN PROPOSED.

In most of the plans which have been proposed, the inventors have not distinctly seen that the influence of the winds and of the movement of air produced by unequal temperatures must be carefully distinguished, and, as far as can be done, provided for.

1. *Openings at once to the Outer Air for Inlets, the Chimney being relied on for the Outlets or Special Tubes fixed in.*—Perforated or air bricks are let into the walls. A usual size is 9 × 3 inches, and the united area of all the several openings in one brick is about 11½ square inches. Another common size is 10 × 6 inches, with an open area of about 24 square inches. The wind blows freely through them, and draughts are produced.

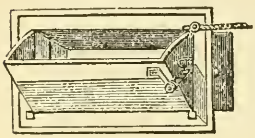

Fig. 14.

The Sheringham valve is a great improvement on this: the air passes through a perforated brick or iron plate, and is then directed upward by a valve opening, which can be closed, if necessary, by a balanced weight (Fig. 14). The size of the internal opening is, in the usual sized valve, 9 inches by 3, and the area is 27 inches. These valves are usually placed toward the upper part of the room. The wind blows through them, and the movement is therefore variable. They are often outlets; it will, in fact, depend upon circumstances whether they are inlets or outlets. Very little draught is, however, caused by them, unless with a high wind; on the whole, they are the best inlets of this kind.

An open iron frame of the size of a brick covered with perforated zinc, and with a valve to close it, if necessary, is a still simpler plan, and the air is pretty well distributed. The gauze should be cleaned frequently. Mr. Boyle, of London, uses a round plate working on a screw, which can be brought nearer or farther from a corresponding opening in the wall; the air entering strikes on the plate, and then spreads circularly over the wall, and is then drawn gently into the room. Some ingenious forms of inlet and outlet have also been introduced by Mr. Richard Weaver, C.E., and by Messrs. Ellison, of Leeds.

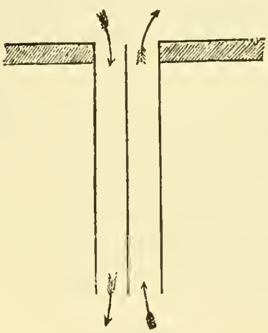

Fig. 15.

2. *Tubes of Different Kinds.*—A single tube has been sometimes used for inlet and outlet, a double current being established. This is, however, a rude plan, as there are no means of distributing the air, and as the intermingling of the current and the friction of the meeting air is sometimes so great as to impede, or even for a time stop, the movement.[1] To avoid these inconveniences, Watson proposed to place a partition in the tube (Fig. 15), and Muir suggested the use of a double partition running from corner to corner, so as to make four tubes. He covered his divided tube with a louvre so as to make use in some degree of the aspiratory power of the wind on one side.

In these tubes, accidental circumstances, such as the sun's rays on one side, the wind, the fire in the room, etc., will determine which is outlet and which is inlet. They are so far better than the single tube, that the partition divides the currents and prevents friction, but there is the same irregular action and changing of currents from accidental circumstances, so that the

[1] The model of Watson's ventilating tube is well adapted for showing how opposing currents of air block each other. Although the tube is of good size, a candle placed in a bell glass, into the top of which the tube is fixed, soon goes out; a partition being then inserted into the tube the currents are at once divided—one passes up, one down, the sides of the tube, and the candle burns again.

direction of the currents and their rate are variable. The distribution of the entering air is also not good.

Much better than these plans is M'Kinnell's circular tube. It consists of two cylinders, one encircling the other, the area of the inner tube and encircling ring being equal.[1] The inner one is the outlet tube ; it is so because the casing of the other tube maintains the temperature of the air in it; and it is also always made rather higher than the other ; above it is protected by a hood, but if it had a cowl, like that at Fig. 12, it would be better. The outer cylinder or ring is the inlet tube ; the air is taken at a lower level than the top of the outlet tube ; when it enters the room, it is thrown up toward the ceiling, and then to the walls by a flange placed on the bottom of the inner tube ; the air then passes from the walls along the floor toward the centre of the room, and upward to the outlet shaft. (Figs. 16 and 17.) Both tubes can be closed by valves. If there is a fire

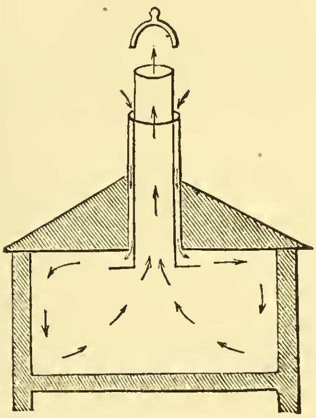

FIG. 16.

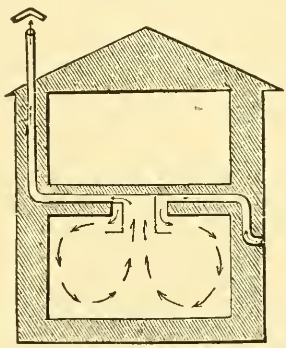

FIG. 17.

in the room, both tubes may become inlets ; to prevent this the outlet tube should be closed ; if doors and windows are open, both tubes become outlets.

The movement of air by this plan is imperceptible, or almost so ; it is an admirable mode for square or round rooms, or small churches ; for very long rooms it is less adapted.

The tube is made of all sizes, from 6 inches in diameter, which is adapted for a sitting-room, up to 7 or 8 feet, which is the size used in some churches. The two tubes, after passing out of the room, may be taken in different directions, care being taken that the inner tube is always the longest, and, if possible, with the fewest curves.

If the two tubes can be kept together for some distance, an advantage would perhaps be gained, as the hot air would transmit a portion of its heat to the air in the outer tube, which would enter the room at a higher temperature than would otherwise be the case ; some loss of movement would result, but this would be trifling.

Dr. Arnott's chimney ventilator is a valved opening at the top of the room, leading at once into the chimney, and, like Dr. Chowne's siphon, has

[1] It would be advisable to make the outer ring larger, seeing that the friction to be overcome is about double that of the inner tube.

the great advantage of drawing the air from the top of the room; it has been, and is, much used, but has the inconvenience of occasionally allowing the reflux of smoke.

Mr. Boyle has altered this chimney ventilator by hanging small talc plates at a certain angle; a very slight pressure closes them and prevents reflux.

Of these various plans, M'Kinnell's should be chosen, if the air must be admitted at the top of the room; and they are well adapted for guard-rooms, cells, and rooms of small dimensions, when it is desired to have the ventilating apparatus out of reach. Watson's divided tube can also be used, but is less useful than the others.

System of Ventilation adopted in the Army.

On Home Service.—The official plan now in use was arranged about twenty-two years ago by the Barrack Improvement Commission; it is applied in most of the new barracks, and in several old ones. It has answered extremely well, and it is much to be desired that it should be carried out everywhere. It is based on the plan of natural ventilation, and consists of—

1. One *outlet* shaft, or more if required, proceeding from the highest point of the room; the exact position in the room varies; it is sometimes at the corner, or at one side, according to circumstances. This shaft is carried straight up inside the wall, and about 4 to 6 feet above the roof, and is covered with a louvre. It is made of wood, is very smooth inside, and is provided with a flap for partly closing it below. Its size is regulated by that of the room and by the number of inmates, but it is not made larger than 1 square foot; if more outlet is required, another shaft is put up. The relation between its size and that of the room varies with the position of the room. In a three-storied barrack the rule is as follows:—

1. On the ground floor, 1 square inch of section area of outlet shaft for every 60 cubic feet of room-space, or for each man 10 square inches of area.
2. On the first floor, 1 square inch for every 55 cubic feet of room-space, or for each man 10.9 (say 11) square inches.
3. On the second floor, 1 square inch for every 50 cubic feet of room-space, or for each man 12 square inches.

In a one-storied barrack the amount should be the same as the second floor, or, in other words, 12 men would have a shaft of 1 square foot. In addition, there is the chimney, which gives a section area per head of about six square inches. The total outlet area per man is therefore 16 to 18 inches, according to circumstances.

2. *Inlets.*—The amount of inlet is a trifle more than 1 square inch to every 60 cubic feet of room.

Half the inlet air is warmed in all the new barracks and many old barracks by being taken through air chambers behind the fire (Galton's stove) (area of tube = 6 square inches per head), and the other half comes direct from the outer air into the rooms through Sheringham valves. Area of outer opening = 5 square inches, making altogether 11 square inches of inlet opening per man.

The cold air inlets (Sheringham valves) are placed at the sides near the

ceiling, about 9 feet from the floor, and are not opposite each other. Fig. 18 shows a usual arrangement. The outlet space is thus seen to be rather larger than the inlet, but as the doors and windows seldom fit close, it is probable that practically this is of little consequence.

The movement of air through these openings is tolerably regular—a regular as it ever can be in natural ventilation. The discharge of air through the chimney and outlet shaft averages about 1,200 cubic feet per head per hour, with a range from 700 to 1,500 or 1,600, according to the amount of fire, the warmth of the room, and the movement of the external air. The usual upward current through the outlet shafts at night, is from 3 to 5 feet per second. Sometimes the chimney and outlet counteract each other a little; a strong chimney draught may stop the current in the outlet shaft, but there is seldom any down-draught unless rain beats into the louvre and trickles down the inside of the shaft. The ventilation of barracks has been wonderfully improved by this plan, and the average CO_2 ranges from .7 to 1 per 1,000 volumes, according to the rapidity of movement of the air.

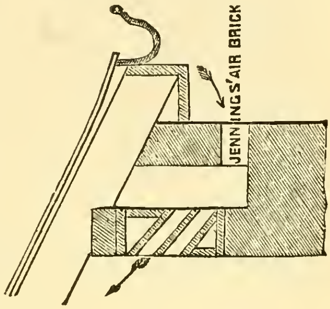

FIG. 18.

The hospital system is precisely the same, except that the dimensions are nearly doubled.

Mediterranean Stations.—The same system is directed to be carried out whenever practicable at Malta and Gibraltar, only the sizes of the inlets and outlets are trebled; for example, there is 1 square inch of outlet for every 20 cubic feet of space instead of 60 as at home; great care is ordered to be taken to remove all outside obstacles to the movement of the wind.

The Tropics and India.—The same system in principle is now directed to be used in India.

SECTION III.

ARTIFICIAL VENTILATION.

Artificial ventilation is accomplished in two ways: either the air is drawn out of a building or room (the method by extraction), or it is driven in, so as to force out the air already in the room (the method by propulsion).

SUB-SECTION I.—VENTILATION BY EXTRACTION.

This is produced by the application of heat, so as to cause an upward current, or by the steam-jet, or by a fan or screw, which draws out the air.

1. *Extraction by Heat.*—The common chimney is a well-known example of this. There is a constant current up the chimney, when the fire is burning, in proportion to the size of the fire and of the chimney. The usual current up a common sitting-room chimney, with a fair fire, is, as measured by an anemometer, from 3 to 6 feet per second, A very large fire will bring it up to 8 or 9 feet. The movement caused by a kitchen or furnace fire is, of course, greater than this. If the area of the section where the anemometer is placed be known, the discharge can be stated in cubic feet.

When the air enters equably, and is well distributed, the movement of air is from the inlets gently toward the fireplace; there is also said to be a movement, from above the fireplace, along the ceiling and down the walls, and then along the floor to the chimney.[1]

In the wards of Fort Pitt the current, with a good fire, is about 3½ to 4½ feet per second; and as the section area of the throat is .5 square foot, the average discharge is about 7,200 cubic feet per hour. In the barracks of Chatham, Dr. Fyffe found the discharge by the chimney to be 9.080 cubic feet per hour (average of six observations). In the barracks at Gravesend, Messrs. Hewlett, Stanley, and Reid found the discharge to be 6,120 cubic feet per hour (average of twenty observations). At Chelsea New Barracks, with a fire alight but low, the velocity was 14.6 per second, or 21,038 cubic feet per hour; and, with the fire out, 11.9 per second, or 17,088 per hour.[2] In the experiments of the Barrack Commissioners,[3] the chimney discharge ranged from 5,300 to 16,000 cubic feet per hour, the mean of twenty-five experiments being 9,904 cubic feet. Even in summer, without a fire, there is generally a good up-current.[4] It may be concluded that, with an ordinary fire, a chimney gives a discharge sufficient for four or five persons. If then, more than this number of persons habitually live in the room, another outlet must be provided.

As the current up the chimney is so great when the fire is lighted, all other openings in a room, if not too many, become inlets; and, in this way, down-draughts of air may occur from tubes intended as outlets. There is no remedy for this; and if too much enters, the outlets must be more or less closed.

If the room be without openings, so that no air can reach the fire, air is drawn down the chimney, and a double current is established, by which the fire is fed. The down-current coming in puffs is one cause of smoky chimneys, and may be at once cured by making an inlet.

The chimney and fire is a type of a number of other similar modes of ventilation by extraction.

The ventilation of mines is carried on by lighting a fire at the bottom of a shaft (the upcast or return shaft), or half a shaft, if there be only one. The air is drawn down the other or downcast or intake shaft, or half the shaft, and is then made to traverse the galleries of the mine, being directed this way or that by partitions. Double doors are used, so that there is no back or side rush of the air. The current passes through the upcast-shaft at the rate of from 8 to 10 feet per second; it flows through the main galleries at the rate of from 4 to 6 feet per second, or even more, and from 1,000 to 2,000 cubic feet per head per hour are supplied in good mines. In fire-damp mines much more than this is given, even as much as 6,000 cubic feet per man per hour.[5] If the quantity of air be reduced too low there is a serious diminution in the amount of work performed by the men. A horse is allowed 2,466 cubic feet, and a light 59 cubic feet per hour. All these quantities are too small. It may easily be conceived how skilfully the air must be directed, so as to traverse the most remote workings; in some mines a portion of air makes a circuit of from 30 to 40 miles before it can

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[1] Reid and Stewart, quoted by the Barrack Commissioners.

[2] Dr. F. de Chaumont's Reports, Army Med. Reports, vol. ix.

[3] Report, 1861, p. 73.

[4] In August, 1869, I found at Fort Elson the velocity to be on one occasion 7.5 per second, and at Gosport New Barracks, 8.4. The velocity generally ranges from 1½ foot to 3 feet per second, although it is often more.—(F. de C.)

[5] Proceedings of Civil Engineers, vol. xii., p. 308.

arrive at the upcast-shaft. The size of the shafts in a colliery varies from 8 to 11 or 12 feet in diameter; the sectional area of a shaft of the former size would be 50 square feet. A current of 8 feet per second in the upcast-shaft would give a discharge of 1,440,000 cubic feet per hour, which would give 720 men 2,000 cubic feet per hour.

The sectional area and height of the extracting shaft, and of the tubes running into it, have been fixed by Péclet; the principle is to give to the shaft the greatest height which can be allowed, and the largest section which can be given,[1] without permitting the temperature of the contained air to fall so low as to be unable to overcome the resistance of the atmosphere at the top of the shaft, or the action of the winds.[2]

In large buildings the same plan is often used; a chimney (*cheminée d'appel* of the French) is heated by a fire at the bottom, and into the bottom of this shaft, close to the fire, run a number of tubes coming from the different rooms. Several French and English hospitals, and many other buildings, are ventilated in this way. Dr. Reid for some years ventilated the Houses of Parliament in the same manner, and so powerful was his up-draught, that he could change the entire air in the building in a few minutes.

In dwelling-houses it has been proposed to have a central chimney, into which the chimneys of all the fires shall open, and to surround this with air-shafts connected with the tops of the rooms. It is supposed that if other inlets exist, there will be a current both up the chimney and up the shaft running beside it.

In all these cases it requires that the workmanship shall be very exact, so that air shall not reach the extracting shaft except through the tubes.

It is now more than a hundred and twenty years ago since Dr. Mead brought before the Royal Society Mr. Sutton's plan of ventilating ships on the same principle. Tubes running from the hold and various cabins joined together into one or two large tubes which opened into the ashpit beneath the cooking fires. If the doors of the ashpits were kept closed, the fires drew the air rapidly from all parts of the ship. Unfortunately, this plan never came into general use. The same plan was adopted by Dr. Mapleton for the ventilation of the hospital ships employed in the last (1860) China War. The arrangement requires some watching to prevent careless cooks from allowing air to reach the fires in other ways.

On the same principle some men-of-war are now being ventilated.[3] The funnel and upper part of the boiler, and, as far as possible, all the steam apparatus, are inclosed in an iron casing, so that a space is left of some 3 or 4 feet between the casing and the funnel. When the fires are lighted, there is of course a strong current up this space, and to supply this the air is drawn down through all the hatchways toward the furnace doors. The temperature of the stokehole is reduced from 130° or 140° Fahr., to 60° and 70°; and the draught to the fires is so much more perfect, that more steam is obtained from the same amount of fuel. This plan, devised by Mr. Baker, has been ingeniously applied by Admiral Fanshawe, late superintendent at Chatham dockyard, to the ventilation of every part of the ship where there are no water-tight compartments. Edmonds' plan com-

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[1] De la Chaleur, 3d. ed., 1861, t. iii., p. 66 et seq.

[2] The amount of the resistance given to the movement of air through the tubes leading to the shaft, and in the shaft itself, can be calculated from the formula given by Péclet at p. 47 (t. iii.), but which it is unnecessary to introduce here.

[3] In the new ironclads it is found necessary to use large fans driven by special engines to effect thorough change of air below.

bines with this the ventilation not only of the hold, but of the timbers of the ship.

Sometimes, instead of a fire at the bottom of the chimney, it is placed at the top; but this is a mistake, as there is a great loss of heat from the immediate escape of the heated air; the proper plan is to heat, as much as possible, the whole column of air in the chimney, which can only be done by placing the fire below. Sometimes, as in Jebb's method for cell-prisons, the shaft is too short for the work it has to do.

Frequently, instead of, or in addition to a fire, heat is obtained in the shaft by means of hot-water or steam pipes. This plan has long been in use in England,[1] and has since been introduced into France, and improved by M. Léon Duvoir. Warming, as well as ventilation, is accomplished by this method, which is in action at the Hospitals Lariboisière (in one-half) and Beaujon. It appears to be at once effectual and economical, though it has been sharply criticised by Grassi and Péclet. After a very long investigation into the merits of all rival plans, it was adopted by a French commission for the warming and ventilation of the Palais de Justice at Paris, and has since been adopted in other public buildings, chiefly from the advocacy of General Morin.[2] The plan at the Hospital Lariboisière is simply this: an extracting shaft contains in the lower part a boiler, from which two spiral hot-water tubes run up to the requisite height in the shaft, and then, leaving it, pass downward and enter the wards, in which they are coiled so as to form hot-water stoves, and then leaving the wards, they pass down and re-enter the boiler. There is a continual circulation of hot water, and in the shaft there is necessarily an upward current of air. But as the air is continually increasing in temperature toward the point of discharge, there is a loss of power, just as in the case of the fire being placed at the top instead of the bottom of the shaft. From the bottom of the wards air-conduits or tubes run into the extracting shaft, and thus the vitiated air is drawn out of the wards. The fresh air is admitted directly from the outside into the wards, and is warmed by being admitted through the coils of the hot-water tubes. In the summer the water is shut off from the water-stoves, but the temperature of the extracting shaft is still maintained.

It is certainly true that the ventilation by this plan is irregular;[3] and also, that in the Hospital Lariboisière, a much greater quantity of air passes through the extracting shaft than enters through the hot-water stoves.

In the summer, when there is ventilation without warming, the outflow of air from the wards varied from 84.4 cubic metres (2,980 cubic feet) to 55.3 cubic metres (1,952 cubic feet) per head per hour.[4]

In the winter, when there are both ventilation and warming, the outflow of air from the wards was 82.2 cubic metres (or 2,902 cubic feet) per head per hour. Of that amount, only 35 cubic metres (1,235 cubic feet) entered by the water-stoves, the rest came in by doors and windows and other openings—an objectionable point, as the air might press in from the closets. Yet, in spite of this, the temperature was maintained pretty well up to the limit fixed in the agreement, viz., 15° Cent. or 59° Fahr.

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[1] It is in use in the Circuit Court-House in Glasgow, and in the Police Buildings at Edinburgh (Ritchie), and in many other buildings.

[2] Two excellent reports have been made by this Commission, of which General Morin was reporter. Their titles are given further on. Much information is also given in General Morin's work on ventilation, Études sur la Ventilation, Paris, 1863, 2 vols.

[3] Péclet, Traité de la Chaleur, 1861, t. iii., p. 267. [4] Grassi, op. cit., pp. 35–37.

Oil has been used in some cases instead of water, for circulating in the heating apparatus.

Very frequently, instead of a fire or hot-water vessels, lighted gas is used to cause a current, and if the gas can be applied to other uses, such as lighting, cooking, or boiling water, the plan is an economical one.

In theatres the chandeliers have long been made use of for this purpose. M. D'Arcet proposed this for several of the old theatres in Paris, and the Commission[1] appointed to determine the mode of ventilation to be adopted in the Théâtres Lyrique et du Cirque Impérial, determined, after much consideration, that this plan was the best adapted for theatres. General Morin, from numerous experiments, found that 1 cubic metre of gas caused the discharge of 1,000 cubic metres of air, or 1 cubic foot would cause the discharge of 1,000 cubic feet of air.[2]

The advantage of extraction by heat, especially in the case of theatres and buildings where gas can be brought into play, are obvious, but the growing use of the electric light will necessarily modify the arrangements for ventilation.

There are some objections to extractions by the fire and hot-air shaft.

(1) The inequality of the draught. It it almost impossible to keep the fire at a constant height. The same quantity of combustible material should be consumed in the same time every day, and the heat should be kept in by large masses of masonry. Still, with these precautions, the atmospheric influences, and changes in the quality of the combustibles, cannot be avoided.

(2) The inequality of the movement from different rooms. From rooms nearest the shaft, and with the straightest connecting tubes, there may be a strong current, while from distant rooms the friction in the conduits is so great that little air may pass. This is well seen in cell prisons, ventilated on Jebb's principle. The greatest care is therefore necessary in calculating the resistance, and in apportioning the area of the tubes to the resistance. This plan is, indeed, best adapted for compact buildings. Occasionally, if the friction be great, from too small size, or the angular arrangement of the conduits leading to the hot-shaft, there may be no movement at all in the conduits, but a down-current to feed the fire is established in the shaft itself—a state of things which was discovered by Dr. Sanderson to exist in the ventilation of St. Mary's Hospital in London.

(3) The possibility of reflux of smoke, and perhaps of air, from the shaft to the rooms, is another objection of some weight.

(4) The impossibility of properly controlling the places where fresh air enters. It will flow in from all sides, and possibly from places where it is impure, as from closets, etc.; air is so mobile that with every care it is difficult to bring it under complete control—it will always press in and out at the point of least resistance.

2. *Extraction by the Steam-jet.*—The moving agent here is the force of the steam-jet, which is allowed to pass into a chimney. The cone of steam sets in motion a body of air equal to 217 times its own bulk. Tubes passing from different rooms enter the chimney below the steam-jet, and the air is extracted from them by the strong upward current. This plan is best adapted for factories with spare steam. It was employed for some time in the ventilation of the House of Lords, but was finally abandoned.

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[1] Rapport de la Commission sur la Chauffage et la Ventilation du Théatre Lyrique et du Theatre du Cirque Impérial, Rapporteur le General Morin, Paris, 1861.

[2] Études sur la Vent., t. ii., p. 720.

3. *Extraction by a Fan or Screw.*—An extracting fan or Archimedean screw has been used to throw out the air. Several different kinds have been proposed by Messrs. Combes, Letoret, Glepin, and Lloyd, and have been used in coal-mines in Belgium, and in some of the English mines. At the Abercarn mine, in South Wales, a fan is used of 13½ feet diameter; the vanes, eight in number, are 3½ feet wide by 3 feet long; at 60 revolutions per minute the velocity of the air is 782 linear feet per minute, and 45,000 cubic feet are extracted; the velocity at the circumference of the fan is 2,545 feet per minute; the theoretical consumption of coal per hour is 17.4 ℔.[1]

Mr. Van Hecke formerly used a fan for this purpose, in his system of ventilation of buildings, but he has found it better to abandon it, and substitute a propelling fan.

Sub-Section II.—Ventilation by Propulsion.

This plan was proposed by Desaguliers, in 1734,[2] when he invented a fan or wheel inclosed in a box. The air passed in at the centre of the fan, and was thrown by the revolving vanes into a conduit leading from the box. In some form or other this fan has been used ever since, and the conduits leading from it are now generally made large, so that the fan may move slowly, and deliver a large quantity of air at a low velocity. The fan, if small, is worked by hand; if larger, by horse, water, or steam power. It is largely used in India, under the name of the Thermantidote.

The fans are often made with six or eight rays, each carrying vanes at the end, which should be as close as possible to the enveloping box. In size, the length of the vanes should be more than half the length of the rays; the number of rays should augment with the diameter of the orifice of access.[3]

The amount of air delivered can be told by timing the speed of revolution of the extremities of the fan per second, or per minute; the effective velocity is equal to $\frac{4}{7}$ths of this, and this is the rate of movement of the air. If the section area of the conduit be known the number of cubic feet discharged per second, minute, or hour, can be at once calculated.

The power of this plan is very considerable. With a fan of 10 feet diameter, revolving sixty times per minute, the effective velocity is 1,414 feet per minute. The rate of movement in the main channel should not be more than 4 feet per second; the conduits must gradually enlarge in calibre; and the movement, when the air is delivered into the rooms, should not be more than 1½ foot per second. At the Hospital Lariboisière in Paris, it is stated that 150 cubic metres (= 4,296 cubic feet) have been delivered per head per hour, in the wards ventilated by the propelling fan of MM. Thomas et Laurens. It must, however, be remembered, that the later observations of General Morin showed that much of the movement ascribed to the fan was really owing to natural ventilation.

This plan is very well adapted for those cases in which a large amount of air has to be suddenly supplied, as in crowded music halls and assembly rooms. St. George's Hall at Liverpool is ventilated in this way. The air

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[1] Ure's Dictionary, 1875, art. Ventilation, vol. iii. p. 1069.

[2] Course of Experimental Philosophy, vol. ii, p. 564. The wheel was shown to the Royal Society in 1734.

[3] Péclet, De la Chaleur, 3d edition, 1868, t. i., pp. 259, 263. Numerous kinds of fans for propulsion and extraction are figured, and detailed accounts of construction and amount of work are given.

is taken from the basement; is washed by being drawn through a thin film of water thrown up by a fountain; is passed into calorifères (in the winter), where it can be moistened by a steam-jet, if the difference of the dry and wet bulb be more than four to six degrees, and is then propelled along the channels which distribute it to the hall. In summer, it is cooled in the conduits by the evaporation of water.

At the Hôpital Necker in Paris, and in many other places, the plan of Van Hecke is in use. A fan, worked by an engine, drives the air into small chambers in the basement, where it is warmed by cockle stoves, and then ascends into the rooms above and passes out by outlet shafts constructed in the walls. The system is effective and economical, though it is only just to say that, the use of the fan excepted, it is precisely similar in principle to Sylvester's.

The fans employed by MM. Verity, of London, seem to be very powerful.

In addition to the fan, other appliances have been used. Soon after Desaguliers proposed the fan, Dr. Hales employed large bellows for the same purpose, and they were used for some time on board some men-of-war, and in various buildings. They were worked by hand; and probably this, and their faulty construction, led to their being disused. Their use was revived and their form modified and improved by Dr. Arnott.[1] Dr. Arnott showed that Hales lost much power by forcing his air through small openings; and, by some ingenious alterations, made an effective machine. The hydraulic air-pump, sometimes used in mines, is useful on a small scale.[2]

The punkah used in India is another mechanical agent with a similar though more imperfect action. When a punkah is pulled in a room open on all sides, it will force out a portion of air, the place of which will be at once supplied by air rushing in with greater or less rapidity from all points. If the punkah can be moistened in any way, its cooling effect is considerable. In Moorsom's punkah a wheel turned by a bullock both moves the punkah and elevates water, which then passes along the top of the punkah, and flows down it.

The advantages of ventilation by propulsion are its certainty, and the ease with which the amount thrown in can be altered. The stream of air can be taken from any point, and can, if necessary, be washed by passing through a thin film of water, or through a thin screen of moistened cotton, and can be warmed or cooled at pleasure to any degree. In fact, the engineer can introduce into this operation the precision of modern science.

The disadvantages are the great cost, the chances of the engine breaking down, and some difficulties in distribution. If the air enter through small openings, at a high velocity, it will make its way to the outlets without mixing. The method requires, therefore, great attention in detail.

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[1] On the Smokeless Fireplace, by Neil Arnott, M.D., F.R.S., etc., 1855, p. 162; and in other publications.

[2] Ure's Dictionary, 1875, vol. iii., p. 1064.

SECTION IV.

RELATIVE VALUE OF NATURAL AND ARTIFICIAL VENTILATION.

Circumstances differ so widely, that it is impossible to select one system in preference to all others. In temperate climates, in most cases, especially for dwelling-houses, barracks, and hospitals, natural ventilation, with such powers of extraction as can be got by utilizing the sources of warming and lighting, is the best. Incessant movement of the air is a law of nature. We have only to allow the air in our cities and dwellings to take share in this constant change, and ventilation will go on uninterruptedly without our care.

In some circumstances, however, as in the tropics, with a stagnant and warm air; and in temperate climates in certain buildings, where there are a great number of small rooms, or where sudden assemblages of people take place, mechanical ventilation must be used. So much may be said both for the system of extraction and propulsion under certain circumstances, that it is impossible to give an abstract preference to one over the other. In fact, it is evident that the special conditions of the case must determine the choice, and we must look more to the amount of air, and the method of distribution, than to the actual source of the moving power. But in either case the greatest engineering skill is necessary in the arrangement of tubes, the supply of fresh air, etc. The danger of contamination of air as it passes through long tubes, and the immense friction it meets with, must not be overlooked. For hospitals, natural ventilation certainly seems the proper plan. The cost of the various plans will depend entirely on circumstances, the nature of the building, the price of materials, coal, etc. On the whole, the plans of ventilating and warming by hot-water pipes, and Van Hecke's plan, are cheaper than the method by propulsion by means of a large fan; but the latter gives us a method which is more under engineering control, and is better adapted for hot climates when it is desired to cool the air.

CHAPTER IV.

EXAMINATION OF AIR AND OF THE SUFFICIENCY OF VENTILATION.

The sufficiency of ventilation should be examined—

1st, By determining the amount of cubic space assigned to each person, and the amount of movement of the air, or, in other words, the number of cubic feet of fresh air which each person receives per hour.

2d, By examining the air by the senses, and by chemical and mechanical methods, so as to determine the presence, and, if possible, the amounts of suspended matters, organic vapor, carbon dioxide, hydrogen sulphide, and watery vapor.

SECTION I.

MEASUREMENT OF CUBIC SPACE.[1]

The three dimensions of length, breadth, and height are simply multiplied into each other. If a room is square or oblong, with a flat ceiling, there is, of course, no difficulty in doing this, but frequently rooms are of irregular form, with angles, projections, half-circles, or segments of circles. In such cases the rules for the measurement of the areas of circles, segments, triangles, etc., must be used. By means of these, and by dividing the room into several parts, as it were, so as to measure first one and then another, no difficulty will be felt. After the room has been measured, recesses containing air should be measured, and added to the amount of cubic space ; and, on the other hand, solid projections, and solid masses of furniture, cupboards, etc., must be measured, and their cubic contents (which take the place of air), deducted from the cubic space already measured. The bedding also occupies a certain amount of space ; a soldier's hospital mattress, pillow, three blankets, one coverlet, and two sheets, will occupy almost 10 cubic feet, about 7 if tightly rolled up. It is seldom necessary to make any deduction for tables, chairs, and iron bedsteads, or small boxes, or to reduce the temperature of the air to standard temperature, as is sometimes done.

A deduction may be made, however, for the bodies of persons living in the room ; a man of average size takes the place of about $2\frac{1}{2}$ to 4 cubic feet of air (say 3 for the average).[2]

In linear measurement, it is always convenient to measure in feet and decimals of a foot and not in feet and inches.[3] If square inches are measured, they may be turned into square feet by multiplying by .007.

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[1] For tables of useful measures, see Appendix B, Vol. II.

[2] The weight of a man in stones, divided by 4, gives the cubic feet he occupies. Thus a man weighing 12 stones occupies 3 cubic feet.

[3] The following table may be found convenient:

Inches.		Decimal parts of a foot.	Inches.		Decimal parts of a foot.	Inches.		Decimal parts of a foot.
12	=	1.00	8	=	0.67	4	=	0.33
11	=	0.92	7	=	0.58	3	=	0.25
10	=	0.83	6	=	0.50	2	=	0.17
9	=	0.75	5	=	0.42	1	=	0.08

RULES—*Area or Superficies.*

Area of circle	=	$D^2 \times .7854$.
" "	=	$C^2 \times .0796$.
Circumference of circle	=	$D \times 3.1416$.
Diameter of circle	=	$C \div 3.1416$.
Area of ellipse	=	Multiply the product of the two diameters by .7854.
Circumference of ellipse	=	Half sum of the two diameters by 3.1416.
Area of a square	=	Square one of the sides, or multiply any two sides into each other.
Area of a rectangle	=	Multiply two sides perpendicular to each other.
Area of a triangle	=	Base $\times \frac{1}{2}$ height, or Height $\times \frac{1}{2}$ base.

FIG. 19.

Area of a parallelogram .... = Divide into two triangles by a diagonal, and take sum of the areas of the two triangles.

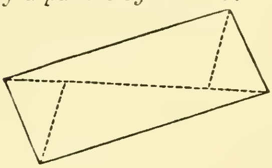

FIG. 20.

Any figure bounded by right lines...... = Divide into triangles, and take the sum of their areas.

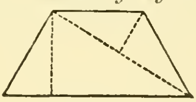

FIG. 21.

Area of segment of circle .... = To $\frac{1}{3}$ of product of chord and height add the cube of the height divided by twice the chord.

$$(Ch \times H \times \tfrac{2}{3}) + \frac{H^3}{2Ch}$$

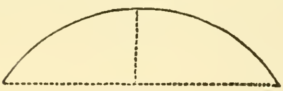

FIG. 22.

Cubic Capacity of a Cube or a Solid Rectangle.—Multiply together the three dimensions, length, breadth, and height.

Cubic Capacity of a Solid Triangle.—Area of section (triangle) multiplied by depth.

Cubic Capacity of a Cone or Pyramid.—Area of base $\times \frac{1}{3}$ height.

Cubic Capacity of a Dome—Two-thirds of the product of the area of the base multiplied by the height (area of base $\times$ height $\times \frac{2}{3}$).

Cubic Capacity of a Cylinder.—Area of base $\times$ height.

Cubic Capacity of a Sphere.—$D^3 \times .5236$.

The cubic capacity of a bell-tent may be taken as that of a cone.

The cubic capacity of an hospital marquee must be got by dividing the marquee into several parts—1st, into body; and 2d, roof:—

1. Body, as a solid rectangle, with a half cylinder at each end.
2. Roof, solid triangle, and two half cones.

The total number of cubic feet, with additions and deductions all made, must then be divided by the number of persons living in the room; the result is the cubic space per head.

SECTION II.

MOVEMENT OF AIR IN THE ROOM.

The direction of movement must first be determined, and then its rate.

1. DIRECTION OF MOVEMENT.

First enumerate the various openings in the room—doors, windows, chimney, special openings, and tubes—and consider which is likely to be the direction of movement, and whether there is a possibility of thorough movement of the air. Then, if it is not necessary to consider further any movement through open doors or windows, close all these, and examine the movement through the other openings. This is best done by smoke disengaged from smouldering cotton-velvet, and less perfectly by small balloons, light pieces of paper, feathers, etc. The flame of a candle, which is often used, is only moved by strong currents. It may be generally taken for granted that one half the openings in a room will admit fresh air, and half will be outlets. But this is not invariable, as a strong outlet, like a chimney, may draw air through an inlet of far greater area than itself, or may draw it through a much smaller area, with an increased rapidity.

2. RATE OF MOVEMENT.

The direction being known, it is only necessary to measure the discharge through the outlets, as a corresponding quantity of fresh air must enter.

By the Anemometer.—This is best done by an anemometer, or air-meter, of which there are several in the market. The one commonly used is in principle that invented by Combes in 1838: four little sails, driven by the moving air, turn an axis with an endless screw, which itself turns some small-toothed wheels, which indicate the number of the revolutions of the axis, and consequently the space traversed by the sails in a given time, say one minute. M. Neumann, of Paris, modified this anemometer by omitting most of the wheels, and introducing a delicate watchmaker's spring, which opposes the force of the wind, and when it equals it, brings the sails to a stand-still. By a careful graduation (which must be done for each instrument), the rate per second is determined, and is indicated by a small dial and index.

Mr. Casella, of Holborn, at the suggestion of the late Dr. Parkes, modified and improved this instrument, and adapted it to English measures. A very beautiful instrument is thus available by which the movement of air can be measured approximatively very readily.

Casella's air-meter is thus used:—Being set at the zero point, it is placed in the current of the air; if it is placed in a tube or shaft, it should be put well in, but not quite in the centre, as the central velocity is always greater than that of the side; a point about two-fifths from the sides of the tube will give the mean velocity. The time when the sails begin to move is accurately noted, and then, after a given time, the instrument is

removed, and the movement, in the time noted, is given by the dial. A correction is then made, and the linear discharge is obtained.[1] If this linear discharge is multiplied by the section-area of the tube or opening (expressed in feet or decimals of a foot), the cubic discharge is obtained. If the current varies in intensity, the movement should be taken several times, and the mean calculated; and if the tube is so small that the sails approach closely to the circumference, the results cannot be depended on. If placed at the mouth of a tube, it often indicates a much feebler current than really exists in the tube.

TABLE *to show the Velocity of Air in linear feet per minute. Calculated from Montgolfier's formula; the expansion of air being taken as* 0.002 *for each degree Fahrenheit, and one-fourth being deducted for friction.* (*Round numbers have been taken.*)

Height of column.	Difference between Internal and External Temperature.																						
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30
10	88	102	114	125	135	144	153	161	169	176	183	190	197	204	210	216	222	228	233	239	244	249	254	279
11	92	107	119	131	141	151	160	169	177	185	192	200	207	213	220	226	233	239	245	250	256	261	267	292
12	96	111	125	136	147	158	167	176	185	193	201	209	216	223	230	237	243	249	255	261	267	273	279	305
13	100	116	130	140	153	164	174	183	192	201	209	217	225	232	239	246	253	259	266	272	278	284	290	318
14	104	120	135	147	159	170	181	190	200	209	217	225	233	241	248	255	262	269	276	282	289	295	301	330
15	108	125	139	153	165	176	187	197	207	216	225	233	241	249	257	264	272	279	286	292	299	305	312	341
16	111	129	144	158	170	182	193	204	213	223	232	241	249	257	265	273	281	288	295	302	309	315	322	353
17	115	133	148	162	176	188	199	210	220	230	239	248	257	265	274	282	289	297	304	311	318	325	332	363
18	118	136	153	167	181	193	205	216	226	237	246	255	264	273	282	290	298	305	313	320	327	335	342	374
19	121	140	157	172	186	198	210	222	233	243	253	262	272	281	289	298	306	314	321	329	336	344	351	384
20	125	144	161	176	190	204	216	228	239	249	259	269	279	288	297	305	314	322	230	338	345	353	360	394
21	128	147	165	181	195	209	221	233	245	255	266	276	286	295	304	313	321	330	338	346	354	361	369	404
22	131	151	169	1[illegible]5	200	214	226	239	250	261	272	282	292	302	311	320	329	338	346	354	362	370	378	414
23	134	154	173	189	204	218	232	244	256	267	278	289	299	309	318	327	336	345	354	362	370	378	386	423
24	136	158	176	193	209	223	237	249	261	273	284	295	305	315	325	335	344	353	361	370	378	386	394	432
25	139	161	180	197	213	227	241	254	267	279	290	301	312	322	332	342	351	360	369	378	386	394	402	441
26	142	164	183	201	217	232	246	259	272	284	296	307	318	328	338	248	358	367	376	385	394	402	410	450
27	145	167	187	205	221	237	251	264	277	290	302	313	324	335	345	355	365	374	383	392	401	410	418	458
28	147	170	190	207	225	241	255	269	282	295	307	319	330	341	351	361	371	381	390	399	408	417	426	467
29	150	173	194	212	229	245	260	274	287	300	312	324	335	347	357	368	378	388	397	407	416	425	433	475
30	153	176	197	216	233	249	264	279	292	305	318	330	341	353	363	374	384	394	404	414	423	432	441	483
31	155	179	200	219	237	253	269	283	297	310	323	335	347	358	369	380	391	401	411	420	430	439	448	491
32	158	182	204	223	241	257	273	288	302	315	328	341	353	364	375	386	397	407	417	427	437	446	455	499
33	160	185	207	226	245	261	277	292	307	320	333	346	358	370	381	392	403	414	424	434	443	453	462	506
34	162	188	210	230	248	265	282	297	311	325	338	351	363	375	387	398	409	420	430	440	450	460	469	514
35	165	190	213	233	252	269	286	301	316	330	343	356	369	381	393	404	415	426	436	447	457	467	476	522
36	167	193	216	236	255	273	290	305	320	334	348	361	374	386	398	410	421	432	442	453	463	473	483	529
37	170	196	219	240	259	277	294	310	325	339	353	366	379	392	404	415	427	438	448	459	470	480	490	5[illegible]6
38	172	198	222	243	262	281	298	314	329	344	358	371	384	397	409	421	432	444	454	465	476	486	496	543
39	174	201	225	246	266	284	302	318	333	348	362	376	389	402	414	426	438	450	461	471	482	492	503	551
40	176	204	228	249	269	288	305	322	338	353	367	381	394	407	420	432	444	455	467	477	488	499	509	558
45	187	216	241	264	286	305	324	341	358	374	389	404	418	432	445	458	471	483	495	506	518	529	540	591
50	197	228	254	279	301	322	341	360	377	394	401	426	441	455	469	483	496	509	522	534	546	558	569	623
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	30

To use the table, determine the height of the warm column of air from the point of entrance to the point of discharge. Ascertain the difference between its temperature and that of the external air. Take out number from table, and multiply by the section-area of the discharge-tube or opening, in feet or decimals of a foot. The result is the discharge in cubic feet per minute, multiply by 60—result, discharge per hour. *Example.*—Height of column, 32 feet; difference of temperature between internal and external air, 17 deg. Looking in the table, we find, opposite to 32 and under 17, 375 feet. That would be for an area of 1 square foot.

But supposing our air opening to be only $\frac{3}{4}$ of a foot, we must multiply 375 by $\frac{3}{4}$ or 0.75 of a foot.

$$\begin{array}{r} 375 \\ .75 \\ \hline 1875 \\ 2625 \\ \hline 281.25 \end{array}$$

Therefore we get 281 feet (per minute), multiplied by 60 = 16,860 feet per hour.

[1] All instruments require correction, as they never give the whole of the velocity. Great care must be taken to ascertain that the correction has been accurately determined, and they should be frequently compared with a standard instrument.

The cubic discharge per minute being known, the amount per hour is got by multiplying by 60, and this, divided by the number of men in the room, gives the discharge per head for that particular aperture.

An anemometer on a larger scale is fixed in some of the large outlets of the Paris hospitals, showing the movement at every moment by means of an index and dial.[1]

By the Manometer.—Dr. Sanderson has made an ingenious alteration of a manometer described by Péclet, which can also be employed to measure the pressure, and by calculation the velocity, of the air. The current of air is allowed to impinge on a surface of water, and the height to which the water is driven up a tube of known inclination and size gives at once a measure of force. But, as necessitating a little calculation, this instrument is less useful than the anemometer, though it is adapted for cases where the anemometer cannot be used, as it may be connected by a long tube with a distant room, and probably would be well fitted to measure constantly the velocity in an extraction shaft.

In measuring the movement of the air in chimneys, or places where either the heat or the dust would injure the air-meter, a manometer must be used. Mr. Fletcher describes what appears to be a good one.[2]

By Calculation.—Supposing the external air is tranquil, and that the only cause of movement is the unequal weights of the external colder and the internal warmer air, the amount of discharge may be approximately obtained by the law of Montgolfier, already given. There is a fallacy, however, as the amount of friction can never be precisely known. Still, as an approximation, and in the absence of an anemometer, the rule is useful; and the accompanying table (p. 194) has therefore been calculated.

On testing this table, however, by the air-meter, it has been found to give too much when the tubes are long, on account of the great friction, and it is therefore advisable to make a further deduction of $\frac{1}{6}$th when the shaft or tube is long, and is at the same time of small diameter. If the tube has any angles, or is curved, this table is too imperfect to be used, unless attention be paid to the correction for friction already noted.

If the movement of the external air influences the movement in the room, as when the wind blows through openings, calculation is useless, and the anemometer only can be depended on.

SECTION III.

EXAMINATION OF THE AIR.

1. BY THE SENSES.

Many impurities are quite imperceptible to smell, but it so happens that animal organic matters, whether arising in respiration or in disease, have, for the most part, a peculiar fetid smell, which is very perceptible to those trained to observe it when they enter a room from the open air. This is, in fact, a most delicate, as well as a ready way of detecting such fetid impurities, and, with a little trouble, the sense of smell may be cultivated to the point of extreme acuteness. Only, it must be remembered, that in a short time the impression is lost, and is not at once regained even in the open air. For a detailed consideration of this question, see Dr. de

[1] Péclet, De la Chaleur, t. i., p. 171, where the description will be found.
[2] Fifth Annual Report of the Inspector under the Alkali Act, Blue Book.

Chaumont's papers in the *Proceedings of the Royal Society*, 1875 and 1876. Among other points, it is shown that the humidity of the air has a very marked influence in rendering the smell of organic matter perceptible, even more powerful than a rise in temperature. Thus the effect of an increase of *one per cent.* in the humidity is as great as a rise of 4.18° Fahr. in temperature, calculated from the mean of 458 fully recorded observations.[1]

As the evidence of the senses, however practically useful, is always liable to be challenged, a more thorough examination of the air must in many cases be made.

2. MICROSCOPICAL AND CHEMICAL EXAMINATION.

The points which should be examined are—[2]

1. The existence and character of suspended matters as judged of by the microscope, both by immediate observation and after cultivation in prepared nutrient fluids.[3]
2. The amount of CO_2, which is taken as a convenient measure of all impurities.
3. The amount of the free or saline ammonia.
4. The ammonia formed by the action of alkaline permanganate on nitrogenous substances floating in the air (albuminoid ammonia).[4]
5. The amount of oxidizable substances, as judged of by the amount of oxygen given off by a standard solution of potassium permanganate.[4]
6. Amount of nitrous and nitric acids.
7. The amount of watery vapor.
8. The presence of H_2S, or other offensive gases and vapors.
9. The presence or absence of ozone.

Microscopical Examination.

1. *Suspended Matters.*[5]—It is probable that the microscopical examination of air will give us in future more important information even than the chemical examination. It is, of course, a merely qualitative test, as there are no means of properly estimating the amount collected.

The suspended matters may be collected very simply by Pouchet's aeroscope. A small funnel is drawn into a small point, below which is a slip of glass moistened with glycerine. The end of the funnel and a slip of glass are inclosed in an air-tight chamber, from which a small glass tube passes out and is connected by india-rubber tubing with an aspirator. As the water runs out through the aspirator, air passes down the funnel and impinges on the glycerine, which arrests any solid particles.

As it is, however, desirable to avoid glycerine, which may (in spite of previous careful examination) contain foreign particles, a still better plan

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[1] Supplementary Note on the Theory of Ventilation, Proceedings of the Royal Society, November 17, 1876.

[2] The amounts of oxygen and nitrogen can also be determined; but very numerous observations have shown that the oxygen often varies within extremely narrow limits, even when there is no doubt of the presence of considerable impurity in the air, so that as far as present knowledge gives, the determination of its amount is no good guide as a general rule.

[3] On this question, see Tyndall on Floating Bodies in the Atmosphere; Miquel, Annuaire de Montsouris, 1882; and Fodor, Die Luft, op. cit.

[4] For these two processes the determination of the organic nitrogen and carbon, by Frankland's method, may be substituted, if practicable.

[5] See page 103 for an account of the suspended matters in air.

is, to take a small bent tube, wash it thoroughly, dry it, and heat it to redness; when cool, it should be placed in a freezing mixture, an india-rubber tube be fixed on one end, and air slowly drawn through; the water of the air condenses in the tube, and many of the solid particles fall with it. A drop is then taken by a perfectly clean glass rod, previously heated to redness, placed on a clean glass, and looked at with an immersion lens, as soon after collection as possible.

Or air may be drawn through pure distilled water, a drop of which is then examined.

The late Dr. Watson (Staff-Surgeon), in his examination of the air at Netley,[1] used fine glass threads soaked in pure glycerine, or dry, and crushed glass; after the air was drawn through, he washed the glass threads with pure water, and then examined the water. These glass threads form good traps for the larger particles.[2] For thorough investigation, however, it is necessary to carry out cultivation experiments, by carrying the air through a sterilized solution, and watching carefully the development of the different organisms. Fodor recommends a solution of isinglass, $1\frac{1}{2}$ to 2 parts in 300 to 400 of pure distilled water, thoroughly boiled, and decanted or filtered.

Miquel has employed a variety of media, some proving more convenient than others for different purposes.

An aspirator, to draw air through the tubes, is very easily made; a square tin vessel, with a tap below, and a small opening above to receive the india-rubber tube, is all that is necessary; fill this with water, and let it run down, and measure the total quantity (in a pint vessel) discharged without tilting the vessel. An imperial pint contains 34.659 cubic inches, and one fluid ounce 1.733 cubic inch. A cubic foot is very nearly 1,000 fluid ounces, and the ounce may be taken as 1.728 cubic inch.[3] The exact delivery of the aspirator is, therefore, easily determined; the air should be drawn slowly through the bent tube in the freezing mixture or through the aeroscope, so that no particles can escape. The use of a large glass or earthenware vessel is perhaps better, as being less liable to error; a piece of india-rubber with a clamp or pinch cock, and a double-tubed india-rubber cap, are all that are required.

Chemical Examination.

2. *Estimation of Carbon Dioxide.*—For our purpose the method proposed by Pettenkofer is the best. A glass vessel is taken capable of holding a gallon, or $4\frac{1}{2}$ litres. The capacity is determined by filling it with water, and by measuring the contents by means of a litre or pint measure (1 oz. = 28.4 cubic centimetres). Angus Smith recommends extracting the air from the bottle by means of bellows. But the most convenient way is simply to fill the vessel with water in the place, the air of which is to be examined, and then to let it drain for a little. When this is done 60 C.C. of clear lime or baryta water are put in, and the mouth is closed with an india-rubber cap.[4] The vessel is agitated so that the lime-water

[1] Army Medical Department Report, vol. xi., p. 529.

[2] I have found carrying the air through a succession of bottles containing pure distilled water the best plan, for the sediment is examined by the microscope, and the liquid part can be used for chemical examinations for organic matter.—(F. de C.)

[3] These numbers are exact at 39° Fahr., or the maximum density point of water.

[4] Should an india-rubber cap not be available, a cork or a bung may be used, tied over with leather or oil-skin; in that case the second alkalinity of the lime-water (if this be used) should be determined as soon after the six or eight hours as possible, certainly within twenty-four hours.

may run over the sides, and then it is left to stand for not less than six or eight hours if lime-water be used; if baryta water be used, the experiment may be completed in a much shorter time, less than one hour. The CO_2 is absorbed by the lime or baryta water, and consequently the causticity of these fluids is, *pro tanto*, lessened. If the causticity of the lime or baryta is known before and after it has been placed in the vessel, the difference will give the amount of lime or baryta which has become united with CO_2.

The causticity of lime is determined by means of a solution of crystallized oxalic acid,[1] 1 C.C. of which exactly neutralizes 1 milligramme (.001 gramme) of lime; 30 C.C. of lime-water are taken, and exactly neutralized; good turmeric paper is the best plan that is usually available for determining the exact point of neutralization, and the margin of the drop gives the most delicate indication. Rosolic acid has, however, been recommended, and also the solution of phenolphthaleine; the latter gives very exact indications. The amount of lime in the 30 C.C. is then equal to the number of C.C. of oxalic acid used; it is always somewhere between 34 and 41 milligrammes.[2]

After the lime has absorbed the CO_2 of the air in the vessel, 30 C.C. of the solution are taken out and tested with the oxalic acid solution as before; the difference shows the milligrammes of lime precipitated by the CO_2. Multiply the difference by 0.795, the result is the C.C. of CO_2 in the quantity of air examined. Deduct 60 C.C. from the total capacity of the jar (to account for the space occupied by the lime-water put in), and state the capacity in litres and decimals; divide the C.C. of CO_2 obtained by the corrected capacity of the jar; the quotient is the C.C. of CO_2 per 1,000 volumes of air.

Example.—The first alkalinity of lime-water was........................	39. for 30 C.C.
After exposure to the air in the jar it was..................	33. "
Difference, being milligrammes of lime....................	6. precipitated by CO_2 in jar.
Multiply by factor............	0.795
	4.770 = Total CO_2 in jar in C.C.
Capacity of jar............................	4,385 C.C.
Deduct 60 C.C. for space taken up by lime-water................................	60
Net capacity............................	=4,325 C.C. = 4.325 litres.

Then $4.770 \div 4.325 = 1.103$ C.C. of CO_2 per litre, or volumes per 1,000.

The factor 0.795 is obtained as follows:—The difference between the two alkalinities expresses milligrammes of lime precipitated by CO_2; from this the milligrammes of CO_2 can be got, by calculating from the ratios of the equivalents, thus:

$$\underset{CaO.}{56} : \underset{CO_2.}{44} :: \underset{\text{Mgm. CaO.}}{a} : \underset{\text{Mgm. of } CO_2.}{x} : \therefore x = a \times \frac{44}{56}.$$

As 1 C.C. of CO_2 at 32° Fahr. (0° Cent.) weighs 1.9767 milligrammes,

[1] See Appendix A, Vol. II.

[2] The amount varies with the temperature, lime being less soluble in hot than cold water; at 60.7° the amount is 38.6, with a difference of +0.1 for every degree below that, and −0.1 for every degree above (Fahr.).

the ratio between weight and volume is $\frac{1}{1.9767} = 0.506$; $\therefore x \times 0.506 =$ C.C. of CO_2, corresponding to the milligrammes by weight. As 60 C.C. of lime-water were put into the jar, and only 30 C.C. taken, the result must be multiplied by 2. Therefore the factors combined are: $\frac{44}{56} \times 0.506 \times 2 =$ 0.795, and this, multiplied by a, the difference between the two alkalinities, gives x, the total C.C. of CO_2 in the jar.

If baryta be used instead of lime, it must be free from traces of potash and soda; a much smaller quantity of liquid may be employed, as it is so much more soluble than lime; the calculation is the same.

A correction for the temperature of the air examined must be made, the standard being 32° Fahr., or 0° C., the freezing-point of water. If the temperature be above this (as it will generally be, at least in buildings) the air will be expanded, and a smaller quantity, by weight, consequently, will be operated on. On the other hand, below 32° the air will be contracted, and a larger quantity, by weight, operated on than at the standard temperature. This can be corrected by adding 0.2 per cent. to the result for every degree above 32°, and subtracting it for every degree below; the reason being that air expands or contracts 0.2 per cent. for every degree (or 1 per cent. for every 5 degrees) it deviates from the standard.

Example.—In the preceding example the CO_2 was found to be 1.103 per 1,000. Suppose the temperature to have been 60° Fahr., then $60-32 = 28°$ to be corrected for; $28 \times 0.2 = 5.6$ per cent. to be added on to result, or the result must be multiplied by $1+.056=1.056$, $\therefore 1.103 \times 1.056 = 1.154$ per 1,000, the corrected result. Suppose the temperature had been 25° Fahr., then $32-25=7°$ to be corrected for; $7 \times 0.2 = 1.4$ per cent. to be deducted, or the result must be multiplied by $1.00-.014=0.986$, $\therefore 1.103 \times 0.986 = 1.087$, the corrected result.

A correction for pressure is not necessary, unless the place of observation be much removed from sea-level; in that case, the barometer must be observed, and a rule of three stated.

$$\left.\begin{array}{l}\text{As standard height of bar:}\\ (=29.92 \text{ in.}=760 \text{ mm.}):\end{array}\right\} \left\{\begin{array}{c}\text{observed height}\\ \text{of bar:}\end{array}\right\} :: a : x.$$

It must be understood that none of the methods hitherto used for the determination of CO_2 in the air give quite accurate results, but the above is the most convenient for ordinary use and is sufficiently accurate for practical purposes. The results differ considerably if the quantities of air treated vary, therefore uniformity in this point is desirable.

Dr. W. Hesse (of Schwarzenberg) has devised an ingenious portable apparatus for determination of CO_2, but the quantities of air treated seem rather too small. The apparatus includes the various apparatus necessary for measuring cubic space, determining air currents, ascertaining the CO_2, and observing the humidity (by Wolpert's hygrometer).

3 and 4. *Estimation of Free Ammonia and of the Nitrogenous Matter in Air by Conversion into Albuminoid Ammonia.*—The nitrogenous matter existing in air may be in the form of dead or living matter of very various kinds. Its determination may be useful as showing that one or other of these classes of substances exists in the air in proportions greater than in pure air. The amount of nitrogen may be estimated in a similar manner to that proposed by Wanklyn and Chapman for water. The late Mr. Chapman,[1] finding that water did not sufficiently absorb the nitrogenous

[1] Chemical News, February 11, 1870.

substances in air, proposed to heat finely powdered pumice-stone to redness, to moisten it with pure water, and then to place it over some coarse pieces of pumice-stone supported on wire in a funnel; a definite quantity of air (say 100 litres) is then drawn through the funnel; the pumice-stone is transferred to a retort containing water freed from ammonia, and distilled as in the determination of the albuminoid ammonia of water. Dr. Angus Smith [1] takes a bottle of about 2,000 C.C. capacity, places in it 30–50 C.C. of the purest water, draws into it the air to be examined, and then agitates the water in the bottle, and proceeds as in Wanklyn's and Chapman's water test. The most convenient way is to draw the air by means of a measured aspirator, through a succession of wash bottles, each containing 100 C.C. of water, perfectly free from ammonia, and then to determine the free and albuminoid NH_3 by Wanklyn's method.

Another plan is to lead a definite quantity of air through a clean curved tube, surrounded by a freezing mixture; the water of the air condenses, and with it much of the organic matter; the tube is then washed out with pure water, the washings are put into a retort with ammonia-free water, and distilled as usual. After passing through the tube the air should be led through pure water to arrest the portion of organic matter that always escapes condensation.

The amount of ammonia (free and albuminoid) is determined as in water analysis. The mere presence of free ammonia may be determined by exposing strips of filtering paper, dipped in Nessler's solution or in etherial solution of the alcoholic extract of logwood; the former becomes yellow, the latter purple.

The quantity of air drawn through must, of course, be accurately determined by a properly arranged aspirator, and the results then calculated in milligrammes per cubic metre.[2]

5. *Estimation of the Oxidizable Matters in the Air in terms of Oxygen.*—In this case a definite quantity of air is drawn through a solution of permanganate of potassium of known strength, and the amount of undecomposed permanganate is determined by oxalic acid. Or part of the water through which the air has been drawn for the ammonia determinations may be examined in the same way as in the case of drinking water. The permanganate acts upon various matters in the air, besides the putrescible organic matters, such as hydrogen sulphide, nitrous acid, tarry matters, etc. The presence or absence of H_2S may be determined qualitatively by means of acetate of lead papers, ammonium sulphide by paper dipped in nitroprusside of sodium; whilst tarry matters would generally be recognized by the smell of the water, or its turbidity. In the absence of these the difference between the permanganate determinations, before and after boiling with sulphuric acid, may be calculated as nitrous acid, as in the case of drinking water; whilst the result after boiling may be reckoned as the oxygen for oxidizable organic matter only.[3]

6. *The Nitrous and Nitric Acids* may also be determined, in the same way as in drinking water, from the washings of the air obtained as above.

All these determinations should be made, when opportunities offer, as the results may prove hereafter of some value.

7. *Watery Vapor.*—The hygrometric condition of the air is ascertained in various ways, especially by the dry and wet bulb thermometer, or by

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[1] Air and Rain, p. 421.
[2] One cubic metre equals 1,000 litres, or 1,000,000 C.C.
[3] See Reports on St. Mary's Hospital, by Dr. F. de Chaumont.

Dines' direct hygrometer. The hair hygrometer of Saussure is also a useful instrument for this purpose, as it marks the degree of humidity very quickly. Wolpert's horse-hair hygrometer may also be used.

8. The presence of H_2S, etc., has been referred to above.

SECTION IV.

SCHEME FOR THE APPLICATION OF THE FOREGOING RULES.

When a ventilation inquiry is about to be made, everything ought to be got ready beforehand. A number of bottles (about 4 to 4½ litres), or glass jars, ought to be carefully measured, and the capacity in C.C. (less 60 C.C. to account for the lime-water) marked upon them ; each bottle ought also to have a closely fitting india-rubber cap and a distinctive number. These bottles are to be used for collecting the samples of air for Co_2. Charges of lime-water (or baryta-water) (each 60 C.C.) ought to be carefully measured off with a burette, or graduated pipette, into small stoppered bottles. Two or more sets of wet and dry bulb thermometers ought to be ready, and two or more series of not less than six bottles, each containing about 100 C.C. of pure distilled water, connected together with glass tubes and india-rubber caps ; also four or more aspirators for drawing the air through the bottles. One of Casella's small air-meters, with a long pole in joints, into which it can be screwed, a measuring tape and foot-rule, a pocket-compass, some pieces of cotton-velvet, a note-book, are also necessary.

When a room has to be examined, enter it after being some time in the open air, and notice if there be any smell ; record the sensation at once in your notes. Hang up the wet and dry bulb thermometer (if it has not been placed there before), and then proceed to take samples of the air for CO_2 ; fill the jars with water, empty them, and allow them to drain ; then pour into each jar the lime-water from one of the small bottles, put on the india-rubber cap, and shake it up. Always take *two* samples at least, and more if a large room. Note the numbers of the bottles. Take the wet and dry bulb readings. Arrange the set of bottles with distilled water in some convenient place, and attach them to one of the aspirators, which may be allowed to flow into another below it. When the upper one is empty it may be changed for the lower one, and so the stream of air may be carried on for any length of time, as seems necessary,—the number of times the aspirators are changed should be duly noted. In determining the carbon dioxide, put out all the lights, or have only sufficient for working purposes ; allow no smoking, and have no person in the room but those who are sleeping there. The aspirators may be allowed to go on continuously, but the examination of the air for CO_2 ought to be repeated at intervals, the exact time of observations being noted. At the same time, similar observations ought to be made in the open air, as nearly as possible simultaneously with those inside. At some convenient time the measurements of the room and the ventilators, the velocities of the currents of air, etc., should be taken on some such plan as the following :—Measure the cubic space, then consider the possible sources of entrance and exit of air ; if there are only doors and windows, notice the distance between them, how they open, on what external place they open ; whether there is free passage of air from side to side ; whether it is likely the air will be properly distributed. On all these points an opinion is soon arrived at.

If there are other openings, measure them all carefully, so as to get their superficies; the chimney must be measured at its throat or smallest part. Determine then the direction of movement of air through these openings by smoke, noting the apparent rapidity. The doors and windows should be closed. When the inlets have been discovered, consider whether the air is drawn from a pure external source, and whether there is proper distribution in the room. Then measure the amount of movement in both inlets and outlets with the anemometer, or calculate by the table if it seems safe to do so.

If the ventilation of the room is influenced by the wind, the horizontal movement of the external air should be determined by Robinson's anemometer, or the little air-meter by Casella may be also used for this purpose, unless the wind be very strong.

In recording the velocity of the air at any openings it is convenient to mark an incoming current with a *plus* sign and an outgoing with a *minus*, thus: + 75 would mean an incoming current at the rate of 75 feet per minute; while − 63 would mean an outgoing current at 63 feet per minute.

When the final analyses are made, and the amount of CO_2 determined, the amount of air per head per hour, supplied and utilized, ought to be calculated out (as before explained), and compared with the amount of movement determined with the air-meter. If the quantities accord fairly, the distribution may be considered good; on the other hand, if they differ, an excess by the air-meter shows bad distribution, whilst a deficiency indicates some other source of incoming air not yet observed.

The water, through which the air has been passed by the aspirator, ought to be examined at once, if practicable; if not, the bottles ought to be carefully stoppered, and the stoppers tied down with leather or strong linen,—when convenient, the sediment should be examined microscopically, and the water (when the sediment has subsided) chemically as before explained. The sediment or a portion of the water should be put into a cultivating solution for further investigation, if opportunity affords.

CHAPTER V.

FOOD.

SECTION I.

GENERAL PRINCIPLES OF DIET.

In the widest acceptation of the term, Food includes every thing ingested, which goes directly or indirectly to the growth or repair of the body, or to the production of energy in any form. In this way it would include not only those organic and mineral solids and the usual beverages recognized as dietetic, but also water and air. For it is quite obvious that without water no function of the living body would be possible, whilst the production of energy is mainly, if not entirely, caused by the union of the atmospheric oxygen with the organic matter of the food or the tissues of the body itself. Although these facts are distinctly recognized, it has generally been the practice to restrict the term "food" to those substances which are capable of oxidation, or those which act as directors or regulators of nutrition, to the exclusion of air and water; these two last being usually considered under separate heads. No one group even of this rough classification is capable of sustaining healthy life alone, and a combination of all, or nearly all, the different constituents of diet is required to accomplish the best results. It is also necessary to limit the appellation, "food," so as to exclude generally medicines and poisons, which, on the one hand, either act, or are intended to act, upon processes of unhealthy nutrition, or, on the other hand, prevent the processes of healthy nutrition, and so induce unhealthy nutrition, and ultimately dissolution. Even here the line cannot be too strictly drawn, for in many cases it is a question more of quantity than kind that determines the direction of the action.

The enumeration and classification of the foods or aliments necessary to maintain human life in its most perfect state have been usually based on the deduction of Prout, that milk contains all the necessary aliments, and in the best form. The substances in milk are—1st, the nitrogenous matters, viz., the casein principally, and in smaller quantities, albumin, lacto-protein, and perhaps other albuminous bodies; 2d, the fat and oil; 3d, sugar in the form of lactin; 4th, water and salts, the latter being especially combinations of magnesium, calcium, potassium, sodium, and iron, with chlorine, phosphoric acid, and in smaller quantities sulphuric acid.

In addition to their occurrence in milk, which is admitted to be a perfect food for the young, this enumeration of aliments appears to be justified by two considerations. First, that the different members of each class, *inter se*, have a remarkably similar composition, while there are broad lines of physical and chemical demarcation between the classes; and secondly, that the different classes appear to serve different purposes in nutrition, and are all necessary for perfect health.

The first point, the similarity of composition among the different mem-

bers of the same class, is obvious enough. The nitrogenous aliments are blood-fibrin, muscle-fibrin or syntonin, myosin, vegetable fibrin, albumin in its various forms, casein (in its animal and vegetable forms), and globulin. Their composition, etc., are remarkably uniform; they contain between 15.4 and 16.5 per cent. of nitrogen, and may be conveniently distinguished by the common term of albuminates. They can replace each other in nutrition. There are some other nitrogenous bodies, such as gelatin and chondrin, and the substances classed under keratin or elastin, which, though approaching in chemical characters to the other substances, are not their nutritive equals.

The second class consists of the various animal and vegetable fats, wax, etc., the composition of which is very uniform, and the chief nutritive differences of which depend on physical conditions of form or aggregation, which conditions cause some fats, when acted upon by the alimentary fluids, to be more easily absorbed than others.

The group of the starchy and saccharine substances (the carbo-hydrates), or of their allies or derivatives (dextrin, pectin), is equally well characterized by chemical resemblances, *inter se*, and differences from the other groups. The several dietetic starches, sugars, including lactin, cellulose (whose want of nutritive power is dependent on form and aggregation, and which requires for digestion a more elaborate apparatus than some animals possess), and the various derivatives of the starches, are all closely allied. There has been some doubt whether pectin should be classed chemically with the sugar and starch group, as the oxygen and hydrogen are not in the proportions to form water, but this is perhaps no objection to its association in a dietetic classification.

The fourth class, consisting of the salts already noted and of water, needs no comment.

The physiological evidence that these classes of aliments serve different purposes in nutrition is not so complete as that of their chemical differences.

A broad distinction must, of course, be drawn between the nitrogenous and non-nitrogenous substances. Late researches, which have much modified our opinion of the direction in which the potential energy of the dietetic principles may be manifested (as heat, or electricity, or mechanical movement), and of the mode in which the nitrogenous substances in particular, aid or restrain this transformation, do not impeach the proposition that the presence of nitrogen in an organized structure, and its participation in the action going on there, is a necessary condition for the manifestation of any energy, or any chemical change. Whether, when energy is manifested, the nitrogenous framework of any nitrogenous structure is a mere stage on which other actors play, or whether it is used up and destroyed, or is, on the other hand, built up or renovated during action, is, so far as classification of food is concerned, a matter of no consequence.

The following considerations seem to prove the necessary participation of the nitrogenous structures in manifestations of energy. Every structure in the body in which any form of energy is manifested (heat, mechanical motion, chemical or electrical action, etc.) is nitrogenous. The nerves, the muscles, the gland-cells, the floating cells in the various liquids, the semen and the ovarian cells, are all nitrogenous. Even the non-cellular liquids passing out into the alimentary canal at various points, which have so great an action in preparing the food in different ways, are not only nitrogenous, but the constancy of this implies the necessity of the nitrogen, in order that these actions shall be performed; and the same constancy of the presence

of nitrogen, when function is performed, is apparently traceable through the whole world. Surely such constancy proves necessity. Then, if the nitrogen be cut off from the body, the various functions languish. This does not occur at once, for every body contains a store of nitrogen, but it is at length inevitable. Again, if it is wished to increase the manifestation of the energies of the various organs, more nitrogen must be supplied. The experiments of Pettenkofer and Voit show that the nitrogenous substances composing the textures of the body determine the absorption of oxygen.[1] The condensation of the oxygen from the atmosphere, its conversion into its active condition (ozone), and its application to oxidation, are according to their experiments entirely under the control of the nitrogenous tissues (fixed and floating), and are apparently proportional to their size and vigor,[2] and to changes occurring in them. The absorption of oxygen does not determine the changes in the tissues, but the changes in the tissues determine the absorption of oxygen. In other words, without the participation of the nitrogenous bodies, no oxidation and no manifestation of energy is possible. The experiments show that the absorption of oxygen by the lungs (blood-composition, and physical conditions of pressure, etc., remaining constant) is dependent on its disposal in the body, and that this disposal is in direct relation with the absolute and relative amount and action of the nitrogenous structures. Mechanical motion, electricity, or heat may be owing to oxidation of fat or of starch, or of nitrogenous substance ; but whatever be the final source, the direction is given by the nitrogenous structures.

The next point is not quite so clear. Are the non-nitrogenous bodies, the fats and the starches, to be again broadly separated into two groups, which cannot replace each other ; or, are these nutritively convertible ? It is now certain that fat may arise from albuminates, so that the nitrogenous substance plays two parts—first, that of the organic framework, *i.e.*, of the regulator of oxidation and of transformation of energy; and, second, it may form a non-nitrogenous substance which is oxidized and transformed.

The experiments of Edward Smith, Fick and Wislicenus, Haughton, and others, on muscular action, prove that we must look for the main source of energy which is apparent during muscular action in the oxidation of non-nitrogenous substances, but no experiments have yet shown whether these are fatty or saccharine. It seems to be inferred that it is fat which is thus chiefly acted upon ; but this opinion is rather derived from a reference to the universal presence of fat when energy is manifested, to the known necessity of it in diet (for though the dog and the rat (Savory) can live on fat-free meat alone, man cannot do so),[3] and from the large amount of energy its oxidation can produce, than from actual observation. If it were true, a broad distinction would be at once drawn between fatty and starchy food, but it is not experimentally proved. If, on the other hand, it were certain that the starchy aliments formed fat in the human body as a rule, this would be a reason for drawing no distinction between the groups. Independent of the argument drawn from bees fed on sugar alone and forming wax, from the fattening of ducks and geese, and the older experi-

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[1] Zeitsch. für Biologie, Band ii., p. 457. See especially, the summary of their opinion at page 571.

[2] When to a diet of meat, which causes a certain absorption of oxygen, fat or sugar is added, the absorption of oxygen lessens (Ranke, Phys. des Menschen, 1868, p. 145) ; so that it is relative as well as absolute amount which comes into play.

[3] Ranke could not maintain himself in perfect nutrition on meat alone.—Physiol. des Menschen, 1868, p. 149.

ments on pigs, the later experiments of Lawes and Gilbert[1] seem to show clearly that the fat stored up in fattened pigs cannot be derived from the fat given in the food, but must have been produced partly from nitrogenous substances, but chiefly from the carbo-hydrates. So also it seems now probable that the fat in milk is not derived at once from blood, but from changes of albumin in the lacteal gland-cells. There seems no reason why we should not extend the inference to man. If so, a man could live in perfect health on a diet composed only of fat-free meat and starch, with salts and water, just as he can certainly live (though perhaps not in the highest health) on meat, fat, salts, and water. The carbo-hydrates would then be proved to be able to replace fats. The experiment has not yet been performed or at least recorded, but it seems important it should be.

Grouven's experiments also suggest that in cattle the carbo-hydrates may split up in the alimentary canal into glycerine, lactic and butyric acids, and carbon dioxide and marsh gas. If this be true, in the herbivora the starches would be merely another form of fat.

An argument against the fats and carbo-hydrates being mutually replaceable under ordinary conditions in the diet of men is drawn from a consideration of the diets used by all nations. In no case in which it can be obtained is an admixture of starch, in some form, with fat omitted. Moreover, in all cases (except in those nations, like the Eskimos, who are under particular conditions of food), we find that the amount of fat taken is comparatively small as compared with that of starches. The fats when taken into the body enter like the albuminates into the structure of the tissues,[2] of which fat forms in probably all cases an essential part. The carbo-hydrates, on the other hand, in the human body do not appear to be parts of the tissues, though they are contained in the fluids which bathe them, or are contained in them. The special direction which the chemical changes in the carbo-hydrates take in the body, seem also to point to special duties. Thus, the formation of lactic and other acids of the same class must arise from carbo-hydrates chiefly or solely. But the formation of these acids is certainly most important in nutrition, for the various reactions of the fluids, which offer so striking a contrast (the alkalinity of the blood, the acidity of most mucous secretions, of the sweat, urine, etc.), must be chiefly owing to the action of lactic acid on the phosphates, or the chlorides, and to the ease with which it is oxidized and removed. If the direction of the changes which the carbo-hydrates undergo within the body is different from that of the fats, the products of these changes must be inferred to play dissimilar parts.

Without pushing these arguments too far, and with the admission that the subject is still obscure, we are fairly entitled to assert that the two groups of fats and carbo-hydrates are not so immediately and completely convertible as to permit us to place them together in a classification of diets.

In the second question to which reference was made, viz., that of a nitrogenous substance furnishing fat, or a carbo-hydrate, the case is simpler. The experiments of Voit, and of Lawes and Gilbert, as well as other considerations, prove that the fat of tissues may be derived from nitrogenous

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[1] On the Sources of the Fat in the Animal Body, Phil. Mag., December, 1866.

[2] The fats appear to pass into the body directly and after saponification, which renders absorption easy. The soap is then, according to Radziejewski's experiments (Virchow's Archiv, Band xliii., p. 268), reconverted into fat. It has been supposed that the greater part of the tissue fat (fat cells) is not derived in this way, but from the tissue albuminates; but Hofmann's experiments and reasonings (Zeitsch. für Biol., Band viii., p. 153) seem to show that the ingested fats are stored up largely. Clinical observations certainly support this view.

substances, and there are reasons to believe that a glycogenous substance may also be derived from albuminates.[1] It is also probable, though not proved, that these non-nitrogenous derivatives may be burnt up in the muscles and other parts, as Fick conjectures.[2] But this cannot allow us to consider an albuminate as an aliment which may replace fat or starch in the case of man. The digestive system of man is framed so differently from that of the carnivora, that fat must be taken in its own form, for it either cannot be formed in sufficient quantity from albuminates, or the body is poisoned by the excess of nitrogen which is necessarily absorbed to supply it.

With regard to the necessity of all four classes of aliments, it can be affirmed with certainty that (putting scurvy out of the question) men can live for some time and can be healthy with a diet of albuminates, fat, salts, and water. But special conditions of life, such as great exercise, or exposure to very low temperature, appear to be necessary, and under usual conditions of life, health is not very perfectly maintained on such diet. It has not yet been shown that men can live in good health on albuminates, carbo-hydrates, salts, and water, etc., without fat.[3]

The exact effect produced by the deprivation of any one of these classes is not yet known. An excess of the albuminates causes a more rapid oxidation of fat (and in dogs an elimination of water), while an excess of fat lessens the absorption of oxygen, and hinders the metamorphosis of both fat and albuminate tissues. The carbo-hydrates have the same effect when in excess, and appear to lessen the oxidation of the two other classes.

It is now generally admitted that the success of Mr. Banting's treatment of obesity is owing to two actions: the increased oxidizing effect on fat, consequent on the increase of meat (especially if exercise be combined), and the lessened interference with the oxidation of fat consequent on the deprivation of the starches.

Health cannot be maintained on albuminates, salts, and water alone; but, on the other hand, it cannot be maintained without them.

The salts and water are as essential as the nitrogenous substances. Lime, chiefly in the form of phosphate, is absent from no tissue; and there is reason to think no cell growth can go on without it; certainly, in enlarging morbid growths and in rapidly growing cells, it is in large amount.

When phosphate of calcium was excluded from the diet, the bones of an adult goat were not found by H. Weiske to be poorer in lime,[4] because probably lime was drawn from other parts; but the goat became weak and dull, so that nutrition was interfered with. Experiment has shown that the growth of wheat is more quickly and effectually checked by the absence of phosphoric acid than of any other constituent from the soil. The lowest forms of life (*Bacteria* and *Fungi*) will not grow without earthy phosphates.

Magnesia is probably also an essential constituent of growth in some tissues. Potash and soda, in the forms of phosphates and chlorides, are

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[1] In addition to physiological evidence from experiments on animals, there are certain forms of diabetes which seem to prove that sugar must be formed either from albuminates or fat, most probably the former.

[2] Archiv. fur ges. Phys., Band v., p. 40.

[3] In some experiments, both with Liebig's essence of meat and Hassall's dried food with bread, Dr. Parkes was very much struck with the bad effect produced on the health of the experimentators, and with the immediate relief given by the addition of butter and a larger supply of starch, without augmentation in the amount of nitrogen.

[4] Zeits. für Biol., Band vii., p. 179

equally important, and would seem to be especially concerned in the molecular currents; forming parts of almost all tissues, they are less fixed, so to speak, than the magnesian and lime salts. It is also now certain, that the two alkalies do not replace each other, and have a different distribution; and it is so far observable, that the potash seems to be the alkali for the formed tissues, such as the blood-cells or muscular fibre; while the soda salts are more largely contained in the intercellular fluids which bathe or encircle the tissues.

The chlorine and phosphoric acid have also very peculiar properties—the former apparently being easily set free, and then giving a very strong acid, which has a special action on albuminates, and the latter having remarkable combining proportions with alkalies. Both are furnished in almost all food; the sodium chloride also separately. Carbonic acid is both introduced and made in the system, and probably serves many uses. Iron is, of course, also essential for certain tissues or parts, especially for the red-blood corpuscles, and for the coloring matter in muscle, and in small quantity is found almost in every tissue, and in every food. The sulphur and phosphorus of the tissues appear to enter especially as such with the albuminates.

Some salts, especially those which form carbonates in the system, such as the lactates, tartrates, citrates, and acetates, give the alkalinity to the system which seems so necessary to the integrity of the molecular currents. The state of malnutrition, which in its highest degree we call scurvy, appears to follow inevitably on their absence; and as they exist chiefly in fresh vegetables, it is a well-known rule of dietetics to supply these with great care, though their nutritive power otherwise is small. So important are those substances, that they might well be placed in a separate class, although Dr. Pavy remarks that "these principles are hardly of sufficient importance, in an alimentary point of view, so called, for their consideration under a distinct head." Surely, this is an under-estimate of their importance, considering the inevitable malnutrition that follows on their absence.

In addition to the substances composing these four classes, there are others which enter into many diets, and which have been termed "accessory foods," or by some writers "force regulators" (like the salts). The various condiments which give taste to food, or excite salivary or alimentary secretions, and tea, coffee, cocoa, alcohol, etc., furnish the chief substances of this class. Much discussion has taken place as to the exact action in nutrition of these substances, but little is definitely known.

A classification, on a simplified plan, may be made as follows:

			Examples.	Functions.
Nitrogenous.	1. *Albuminates.* All substances containing nitrogen, of a composition identical with, or nearly that of albumin; proportion of nitrogen to carbon being nearly as 2 to 7, or 4 to 14.	Animal.	Albumin, Fibrin, Syntonin, Myosin, Globulin, Casein,	Formation and repair of tissues and fluids of the body. Regulation of the absorption and utilization of oxygen. May also form fat and yield energy under special conditions.
		Vegetable.	Glutin, Legumin,	
	*** Substances containing a larger proportion of nitrogen are apparently less nutritious. Proportion of nitrogen to carbon about 2 to 5½, 4 to 11.		Gelatin, Ossein, Chondrin, Keratin,	These perform the above functions less perfectly, or only under particular circumstances.

	Class	Examples.	Functions.
Non-nitrogenous substances.	2. *Fats* (or Hydro-Carbons). Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the proportion of oxygen being *less* than sufficient to convert all the hydrogen into water. Proportion of unoxidized hydrogen to carbon about 1 to 7.	Olein, Stearin, Margarin,	Supply of fatty tissues; nutrition of nervous system? Supply of energy and animal heat by oxidation.
	3. *Carbo-hydrates.* Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being exactly sufficient to convert all the hydrogen into water. Proportion of water to carbon being about 3 to 2.	Starch, Dextrin, Cane sugar, Grape sugar, Lactin (or milk sugar),	Production of energy and animal heat by oxidation. Conversion into fat by de-oxidation.
	3 (*a*). *Vegetable acids* (*and pectous substances?*) Substances containing no nitrogen, but made up of carbon, hydrogen, and oxygen; the oxygen being generally in greater amount than is sufficient to convert all the hydrogen into water.	Oxalic acid, Tartaric ", Citric ", Malic " — In these the oxygen is *more* than sufficient to convert all the hydrogen into water. Acetic ", Lactic " — In these there is no excess of oxygen.	Preserving the alkalinity of the blood by conversion into carbonates; furnish a small amount of energy or animal heat by oxidation.
Mineral.	4. *Salts* (mineral).	Sodium chloride, Potassium ", Calcium phosphate, Magnesium ", Iron, etc.	Various: support of bony skeleton, supply of HCl for digestion, etc. Regulators of energy and nutrition.

Sub-Section I.—Quantity of each Class of Proximate Aliment in a Good Diet for Healthy Men.

We cannot deduce these quantities from milk, for this, though it is a perfect food for the young, does not contain the various constituents in the best proportions for adults. The relative amounts have, therefore, been determined partly by observation on a great number of dietaries, and partly by physiological experiments. The general results of the whole are given in the following tables:—

Average Daily Diet of Men in Quietude.

	Subsistence Diet (Playfair).		Rest.	
	Ounces Avoir.	Grammes.	Ounces Avoir.	Grammes.
Albuminates	2.0	57	2.5	71
Fats	0.5	14	1.0	28
Carbo-hydrates	12.0	340	12.0	340
Salts	0.5	14	0.5	14
Total water-free food	15.0	425	16.0	453

The *subsistence* diet is calculated as sufficient for the internal mechanical work of the body, but it is doubtful if an average man could exist on it without losing weight, as it supposes absolute repose.

The diet for *rest* supposes very gentle exertion, and is probably the minimum for a male adult of average size and weight, say 150 ℔ or 67 kilogrammes.

Each constituent above named is, theoretically, absolutely water-free, but practically the amount of water present in the so-called solid food would be from 100 to 150 per cent. more, so that the weights respectively would be about 32 to 40 ounces gross (907 to 1,134 grammes).

For mere subsistence, without doing visible work, a man therefore requires about $\frac{1}{10}$ of an ounce of water-free food for each ℔ weight of his body, or about $\frac{1}{150}$ of his total weight every twenty-four hours.

Of the standard diets given in the next table, Moleschott's scale has been pretty generally accepted, but the fat is perhaps rather low.

Assuming the water-free food to be 23 ounces, and a man's weight to be 150 ℔, each ℔ weight of the body receives in twenty-four hours 0.15 ounces, or the whole body receives nearly $\frac{1}{100}$ part of its own weight.

This is the dry food, but a certain amount of water (between 50 and 60 per cent. usually) is contained in ordinary food, and adding this to the water-free solids, the total daily amount of so-called dry food (exclusive of liquids) is about 48 to 60 ounces. In addition to this, from 50 to 80

Standard Daily Diets for a Man in Ordinary Work.

	Moleschott.		Pettenkofer and Voit.[1]		Ranke.[2]		Means.	
	Oz. Av.	Gram.	Oz. Av.	Gram.	Oz. Av.	Gram.	Oz. Av.	Gram.
Albuminates	4.59	130	4.83	137	3.52	100	4.31	122
Fats	2.96	84	4.12	117	3.52	100	3.53	100
Carbo-hydrates	14.26	404	12.40	352	8.46	240	11.71	332
Salts	1.06	30	1.06	30	0.89	25	1.70	28
Total water-free food	22.87	648	22.41	636	16.39	465	20.65	582

ounces of water are taken in some liquid form, making a total supply of water of 70 to 90 ounces, or on an average 0.5 ounce for each ℔ weight of body.

This average amount of food and water varies considerably from the following causes :—

1. Individual conditions of size, vigor, activity of circulation, and of the eliminating organs, etc. No men eat exactly the same, and no single standard will meet all cases.[3] The usual average range in different male

[1] Zeitschrift für Biologie, Band ii., p. 523. Somewhat different quantities are given by Voit in his later researches made with Forster, Renk, and Schuster (Munich, 1877), the fat during work being much increased. See Flügge, Lehrbuch der hygienischen Untersuchungsmethoden, Leipzig, 1881. [2] Physiologie des Menschen, 1868, p. 158.

[3] This has been well exemplified in our convict prisons, in which, as a matter of convenience, soldiers are sometimes confined. The ordinary diet, which is sufficient for the convict, is insufficient for the soldier, and that for several reasons: 1. The convict is a smaller man on the average. 2. The previous life of the convict is an irregular one, in which his food is generally insufficient; whereas the soldier's life is usually the opposite, his food is fairly good and his meals regular. 3. The crimes for which the convict is imprisoned are crimes against society, and his removal to a prison cannot be considered much of a degradation morally, whereas his physical condition is really improved. On the other hand, the soldier's crime is often one of a military character only, hence his removal to a prison is a moral degradation, especially if it be a convict prison. The result is, that, whilst the majority of the civil prisoners retain their weight or even

adults is from 40 to 60 ounces of so-called solid food, and from 50 to 80 ounces of water.

2. Differences of exertion. If men are undergoing great exertion they take more food, and, if they can obtain it, the increase is especially in the classes of albuminates and fat, as shown in the next table.

This would represent of so-called solid food from 66 to 77 oz. (1,970 to 2,180 grammes).

The amount of water is also increased, but is very various according to circumstances, and is apparently not so much augmented as the solid food.

3. Differences of climate. It is a matter of general belief that more food is taken in cold seasons and in cold countries than in hot. It is supposed that more energy in some form (finally in that of heat) is necessary, and more food is required ; but there may be other causes, such as varying exertion.

Average Daily Water-free Diet required for an adult Man in very laborious Work,[1] or of a Soldier on Service and in the Field.

	Ounces Avoir.	Grammes.
Albuminates	6.0 to 7.0	170 to 198
Fats	3.5 to 4.5	99 to 128
Carbo-hydrates	16.0 to 18.0	454 to 510
Salts	1.2 to 1.5	34 to 43
Total water-free food	26.7 to 31.0	757 to 879

The following may be taken as an approximative basis for the calculation of diets according to size and work :—

Proximate Aliment.	For subsistence during rest.		For work of about 300 foot-tons per diem.		For work of about 100,000 kilog.-metres per diem.	
	Ounces Avoir. per lb. of body weight.	Grammes per kilogramme of body weight.	Ounces Avoir. per lb. of body weight.	Amount to be added to subsistence diet per lb. of body for every foot-ton of work. Ounces Avoir.	Grammes per kilogramme of body weight.	Amount to be added to subsistence diet per kilogr. of body weight for every 1,000 kilog.-metres of work. Grammes.
Albuminates	.017	1.1	.031	.00005	1.9	.008
Fats	.007	0.4	.019	.00004	0.9	.005
Carbo-hydrates,	.080	4.9	.095	.00005	7.2	.023
Salts	.003	0.2	.007	.00001	0.4	.002
Total	.107	6.6	.152	.00015	10.4	.038

gain, the majority of soldier prisoners lose. It is also found that age has an effect, the older men losing, the younger generally gaining. Length of sentence has also an influence, partly on account of some difference of diet and work, but probably chiefly on account of the system ultimately accommodating itself to the altered conditions. Thus the men who lose weight are, the heaviest originally, the oldest, those with shortest sentences ; those who are stationary or gain weight are, the lightest originally, the youngest, those with longest sentences. For the data, from which the above conclusions are drawn, I am indebted to Brigade-Surgeon J. G. Marston, M.D.—(F. de C.)

[1] Playfair gives the diet of a prize-fighter in training as 9.8 ozs. albuminates, 3.1 fats, and 3.27 starch and sugar. There were 690 grains of nitrogen, and 4,366 grains of carbon.

Beyond 300 foot-tons (or 100,000 kilogramme-metres) the addition would require to be greater.

Proximate Aliment.	For work of 450 to 500 foot-tons per diem.		For work of about 150,000 kilogramme-metres per diem.	
	Ounces Avoir. per lb. of body weight.	Amount to be added to ordinary work diet per lb. of body weight for every foot-ton of work beyond 300.	Grammes per kilogramme of body weight.	Amount to be added to ordinary work diet per kilogramme of body weight for every 1,000 kilog.-metres beyond 100,000.
Albuminates........	.047	.000107	2.9	.020
Fats...............	.030	.000068	1.9	.020
Carbo-hydrates	.120	.000166	7.6	.008
Salts...	.010	.000020	0.6	.004
Total........	.207	.000361	13.0	.042

In the case of any diet, the articles of which are known, the amounts of the four classes of alimentary principles may be calculated from a table of mean composition. The following table is compiled from, in most

Table for Calculating Diets.

Articles.	In 100 Parts.				
	Water.	Albuminates.	Fats.	Carbo-hydrates.	Salts.
Meat of best quality, with little fat, like beefsteaks.................	74.4	20.5	3.5	....	1.6
Uncooked meat of the kind supplied to soldiers, — beef and mutton. Bone constitutes ⅕th of the soldier's allowance [1]...............	75	15	8.4	....	1.6
Uncooked meat of fattened cattle. Calculated from Lawes' and Gilbert's experiments. These numbers are to be used if the meat is very fat......................	63	14	19	....	3.7
Cooked meat,[2] roast, no dripping being lost. Boiled assumed to be the same	54	27.6	15.45	....	2.95
Corned beef (Chicago) [3]...........	40	40	15	....	5
Salt beef (Girardin)...............	49.1	29.6	0.2	....	21.1
" pork (Girardin)...............	44.1	26.1	7.0	....	22.8
Fat pork (Letheby)...............	39.0	9.8	48.9	....	2.3

[1] The gelatine of the meat is reckoned with the albuminates; it is not certain what deduction should be made on account of its lower nutritive value, which is about one-fourth that of albumen (Bischof).

[2] These numbers are taken from John Ranke's analysis.

[3] This is excellent meat, palatable and nutritrious: half a pound would form an ample ration for the field, with the due proportion of biscuit, etc. As it is merely *corned* and not *salted* like ordinary salt meat, it is probable that its constituents may be allowed nearly their full nutritive value.

Table for Calculating Diets.—Continued.

Articles.	In 100 Parts.				
	Water.	Albuminates	Fats.	Carbohydrates.	Salts.
Dried bacon (Letheby)	15.0	8.8	73.3	....	2.9
Smoked ham (J. König)	27.8	24.0	36.5	....	10.1
Horse flesh (J. König)	74.3	21.7	2.6	....	1.0
White fish (Letheby)	78.0	18.1	2.9	....	1.0
Poultry (Letheby)	74.0	21.0	3.8	....	1.2
Bread, white wheaten, of average quality	40	8	1.5	49.2	1.3
Wheat flour, average quality	15	11	2	70.3	1.7
Biscuit	8	15.6	1.3	73.4	1.7
Rice	10	5	0.8	83.2	0.5
Oatmeal (Letheby)	15	12.6	5.6	63.0	3
Maize (Poggiale) (cellulose excluded)	13.5	10	6.7	64.5	1.4
Macaroni (König)	13.1	9.0	0.3	76.8	0.8
Millet (König) (cellulose excluded)	12.3	11.3	3.6	67.3	2.3
Arrow-root	15.4	0.8	....	83.3	0.27
Peas (dry)	15	22	2	53	2.4
Potatoes	74	2.0	0.16	21.0	1
Carrots (cellulose excluded)	85	1.6	0.25	8.4	1.0
Cabbage	91	1.8	0.5	5.8	0.7
Butter	6	0.3	91	....	variable taken as 2.7
Egg (10 per cent. must be deducted for shell from the weight of the egg)	73.5	13.5	11.6	....	1
Cheese	36.8	33.5	24.3	....	5.4
Milk (sp. gr. 1,029 and over)	86.8	4	3.7	4.8	0.7
Cream (Letheby)	66	2.7	26.7	2.8	1.8
Skimmed milk (Letheby)	88	4.0	1.8	5.4	0.8
Sugar	3	....	....	96.5	0.5
Pemmican (de Chaumont)[1]	7.2	35.4	55.2	....	1.8

cases, several analyses by different authors, those analyses being selected which seem best to represent the food of the soldier.[2]

The mode of using the table is very simple: the quantity of uncooked meat or bread being known, and it being assumed or proved that there is no loss in cooking, a rule-of-three brings out at once the proportions. Thus, the ration allowance of meat for soldiers being 12 ounces, 2.4 ounces, or 20 per cent., is deducted for bone, as the soldier does not get the best parts. The quantity of water in the remaining 9.6 ounces will be $\frac{75 \times 9.6}{100} = 7.2$, and the water-free solids will be 2.4 ounces. The albuminates will be 1.44 ounce; the fats, .8064; and the salts, .1536 ounce.

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[1] The sweet pemmican used in the Arctic Expedition of 1875–76 was similar to the above (the ordinary pemmican used in the same expedition), with the addition of about 5 per cent. of cane sugar. In other cases, particularly in the American pemmican, raisins and currants are added. (See Report of Committee on Scurvy for analyses by Professor Frankland and Dr. de Chaumont.) A little pepper is added, not reckoned quantitatively in the above analysis, but probably included in the "loss," *i.e.*, the difference between the sum of the above constituents and 100.

[2] Of course, such tables are merely approximative; but they are very useful as giving a general idea of a diet, although they are not accurate enough to be used in physiological inquiries.

Whenever practicable, the nutritive value should be calculated on the raw substance, as the analyses of cooked food are more variable. It must then be seen that no loss occurs in cooking.

In the case of salt beef or pork, it is not certain how the value should be calculated. The analysis by Girardin[1] for uncooked salt beef (American) is given in the table, but the analysis of the brine shows that much of the nutritious matters, organic and mineral (phosphoric acid, lactic acid, magnesia), have passed out of the meat.[2] Liebig has reckoned the nutritive loss at one-third, or even one-half. It appears from Kühne's observations, that myosin is soluble in a 10 per cent. solution of chloride of sodium, and hence a large quantity of this substance necessarily passes into the brine. Analyses show, it is true, a large percentage of fibrin and cellular tissue in salt meat, but this is made up of indigestible nitrogenous substances, which afford, probably, little real nutritive material. Perhaps salt beef may be reckoned as equal to two-thirds the quantity of fresh beef; this estimate is certainly quite high enough.

The proportion of the nitrogenous substances to the fats, carbo-hydrates, and salts in the standard diet is as follows:—

	Moleschott.	Pettenkofer and Voit.	Ranke.	Mean.
Albuminates	100	100	100	100
Fats	65	87	100	82
Carbo-hydrates	315	258	240	272
Salts	23	22	25	23

Amount of Nitrogen and Carbon.—As the phenomena of nutrition are chiefly owing to the various chemical interchanges of nitrogen and carbon, and in some cases of hydrogen, with oxygen, it may be desired to calculate the amount of these constituents in any diet. This may be done in two ways.

1. Calculate out the dry albuminates, fat, and carbo-hydrates in ounces, and then use the following table:—

Water-free constituents.	Nitrogen, grains.	Carbon, grains.	Hydrogen, grains.	Sulphur, grains.
Albuminate: 1 ounce contains	69	212	13	8
Fat: 1 ounce contains	..	336	48	..
Carbo-hydrates:				
(*a*) Starch: 1 ounce contains	..	194	..	..
(*b*) Cane-sugar: 1 ounce contains	..	184	..	..
(*c*) Lactin: / Glucose: } 1 ounce contains	..	175	..	..

The total amount of carbon in one ounce of albuminate is 233 grains, but of this about 29 grains are converted into urea, and are therefore oxidized

[1] Comptes Rendus, xli., 756.

[2] Liebig found that the brine is saturated with the juice of meat, and Mr. Whitelaw (Chemical News, March, 1864) has shown that extract of meat may be obtained by dialysis from the brine.

only as far as carbon monoxide ; making allowance for this, we have a net total equal to 212 grains of carbon fully oxidized.

2. In the following table, the calculation of these ingredients per ounce has been made ; the substance being supposed to be in its natural state, and to have the composition already assigned to it in the former table.

Substance.	One ounce (=437.5 grains) contains in its natural state in grains.					
	Water.	Nitrogen.	Carbon, capable of being oxidized.	Hydrogen, capable of being oxidized.	Sulphur, capable of being oxidized.	Salts.
Uncooked meat (beef) of the best quality	326	14.14	55	4.4	1.6	7
Uncooked meat as supplied to soldiers	328	10.35	60	6.0	1.2	7
Uncooked fat meat (beef)	276	9.6	94	10.9	1.1	16
Cooked meat	236	19.0	110	11.0	2.2	13
Corned beef (Chicago)	175	27.6	135	12.4	3.2	21
Salt beef	215	20.4	63	3.9	2.4	92
Salt pork	193	18.0	79	6.8	2.1	100
Fat pork	170	6.8	185	24.8	0.8	10
Dried bacon	66	6.1	265	36.8	0.7	12
Smoked ham	122	16.6	174	20.6	2.0	44
Horse flesh	325	15.0	55	4.0	1.7	4
White fish	341	12.5	48	3.7	1.5	4
Poultry	324	14.5	57	4.5	1.7	5
Bread	175	5.5	116	1.7	0.6	5
Wheat flour	66	7.6	166	2.4	0.9	7
Biscuit	35	10.8	180	2.6	1.3	7
Rice	44	3.5	175	3.3	0.4	2
Oatmeal	66	8.7	168	4.8	1.1	13
Maize	59	7.0	169	1.4	0.8	6
Macaroni	57	6.2	169	2.9	0.7	3
Millet	54	7.8	166	2.5	0.9	10
Arrow-root	57	0.5	162	....	...	...
Peas (dried)	66	15.2	156	3.9	1.7	10
Potatoes	324	1.4	45	0.4	0.2	4
Carrots	372	1.1	20	0.4	0.1	4
Cabbage	398	1.2	17	0.5	0.1	3
Butter	26	0.2	312	43.7	...	12
Eggs	322	9.3	68	7.4	1.1	4
Cheese	161	23.2	153	16.0	2.7	24
Milk (sp. gr. 1,029 and over)	380	2.75	30	2.3	0.3	3
Cream	289	1.9	100	13.1	0.2	8
Skimmed milk	385	2.8	24	1.2	0.3	3
Sugar	13	....	178	....	...	2
Pemmican	31	24.4	250	31.1	2.7	8

The standard daily diet for an adult man in ordinary work (Moleschott), calculated in this way, gives—

Nitrogen	317	grains.
Carbon	4,750	"
Hydrogen	202	"
Sulphur	24	"
Salts	461	"

Not infrequently the standard is stated as 20 grammes of nitrogen, and 300 grammes of carbon ; this is equal to 308.6 and 4,629 grains.

The usual range is from 250 to 350 grains of nitrogen for adult men,

and the extreme range is from 2 to 7 ounces of dry albuminate, or from 138 grains of nitrogen (which is the smallest amount necessary for the inner movements of the body, and the bare maintenance of life, as calculated by Playfair), to 483 or 500 grains, which is the amount taken under very great exertion. Edward Smith's careful observations on ill fed and fairly fed operatives, give a range of from 135 grains of nitrogen and 3,271 grains of carbon (in London needlewomen) to 349 grains of nitrogen and 6,195 grains of carbon (in Irish farm laborers). Usually, however, in what are almost starvation diets, the nitrogen is 180 to 200 grains, and the carbon from 3,900 to 4,300 grains (Edward Smith's investigations into the food in Lancashire during the cotton famine). In convict prisons, Dr. Wilson tells us that the men on light labor receive 224 grains of nitrogen and 4,651 grains of carbon, and this is sufficient. Those on hard labor receive 255 grains of nitrogen and 5,289 grains of carbon, and on this diet they lose weight, and have to be continuously shifted from heavy to lighter work. In the case of military prisoners at hard labor even 281 grains of nitrogen and 5,373 grains of carbon were insufficient to prevent men losing weight. In India an improved diet was introduced by the late Surgeon-General Beatson, C.B., in which the nitrogen was about 300 grains and the carbon about 5,300. This appears to have been sufficient to prevent loss of weight, although there was a deficiency of fat. The carbon ranges in various diets, from 3,600 to 5,800 or 6,000 grains. The amount of the salts (461) appears rather large; it is difficult to test it by determining the salts in the excreta, as so much sodium chloride and lime salts are lost through the skin, and some of the excreted salts may also be mere surplusage. The salts seem to be made up of chlorine, 120 grains; phosphoric acid, 50 grains; potash, 40; soda, 40; lime, about 4 grains by the urine (Byasson), and some by the bowels; magnesia, 4.7 grains by the urine, and a considerable amount by the bowels; and iron, the amount of which is uncertain.

Actual experiment has, to a great extent, confirmed the conclusions drawn from a study of these dietaries. Pettenkofer and Voit, in two healthy men, determined many times the amount of nitrogen during common exercise, and found it to be 19.82 grammes, or 305.8 grains. Dr. Parkes experimented on four healthy average men in common work, and found the amount which kept them in perfect health and uniform weight was 293 to 305 grains of nitrogen in twenty-four hours. All these determinations are near Moleschott's numbers. The amount of carbon is, however, perhaps too large. A certain proportion between the carbon and nitrogen ought to be maintained; in the best diets this is: Nitrogen 1 to carbon 15.[1]

Sub-Section II.—On the Energy Obtainable from the Various Articles of Food.

The possible amount of energy which can be manifested in the body will be the result of two conditions: first, the amount of potential energy stored up in the food, which is, of course, easily determined and expressed in terms of units of heat or of motion; and second, the extent to which the processes in the body can liberate and apply this energy. For example, an ounce of albumen can give rise to a certain heating effect, if it be burnt in oxygen; but in the body thorough oxidation can never occur, for some (about one-third) of the constituents of the albumen pass out incompletely

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[1] The Soldier's Ration, by F. de Chaumont, Sanitary Record, February 5, 1876.

oxidized in the form of urea. An ounce of sugar, on the other hand, is as a general rule destroyed to the fullest extent, and ends in carbon dioxide and water, and its actual energy in the body, under whatever form it appears, is equal to its theoretical energy.

One ounce of dry albuminate yields.....	173	foot-tons of potential energy.	
" " fat	378	"	"
" " starch	138	"	"
" " cane-sugar............	131	"	"
" " lactin or glucose......	124	"	"
One grain of carbon (converted into CO_2)	0.710	"	"
" hydrogen (water)..........	3.000	"	"
" sulphur (SO_2).............	0.205	"	"
" phosphorus (P_2O_5)........	0.510	"	"
" carbon (forming urea)......	0.198	"	"

In the following table (page 218) Dr. Frankland's experimental results have been selected as the most exact, but they agree very closely with the theoretical results, particularly with those given by Playfair [1] and others. Some of the numbers are calculated from the ascertained composition of the substance.

A table of this kind is useful in showing what can be obtained from our food, but it must not be supposed that the value of food is in exact relation to the possible energy which it can furnish. In order that the energy shall be obtained, the food must not only be digested and taken into the body properly prepared, but its energy must be developed at the place and in the manner proper for nutrition. The mere expression of potential energy cannot fix dietetic value, which may be dependent on conditions in the body unknown to us. For example, it is quite certain, from observation, that gelatine cannot fully take the place of albumen, though its potential energy is little inferior,[2] and it is easily oxidized in the body. But owing to some circumstances, yet unknown, gelatine is chiefly destroyed in the blood (?) and gland-cells, and its energy, therefore, has a different direction from that of albumen. The tables of energy give broad indications, and can be used in a general statement of the value of a diet; but at present they do not throw light on the intricacies of nutrition.

Sub-Section III.—On the Relative Value of Food of the same Class.

The chemical composition of animal and vegetable albuminates is very similar, and they manifestly serve equal purposes in the body. The meat-eater, and the man who lives on corn, or peas and rice, are equally well nourished. But it has been supposed that either the kind or the rapidity of nutrition is different, and that the man who feeds on meat, or the carnivorous animal, will be more active, and more able to exert a sudden violent effort, than the vegetarian, or the herbivorous animal, whose food has an equal potential energy, but which is supposed to be less easily evolved. The evidence in favor of this view seems very imperfect. The rapid move-

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[1] On the Food of Man in Relation to his Useful Work, 1865.

[2] One gramme of dry isinglass will develop 4,520 heat-units when burnt in oxygen; one gramme of dry boiled ham, 4,343; one gramme of dry beef, 5,313 heat-units. (Frankland, Philos. Mag., September, 1866, p. 169.) The potential energy of isinglass is more than that of ham, but its nutritive power is far inferior.

Energy Developed by One Ounce of the following Substances when Oxidized in the Body.

Name of Substance.	In usual state, with the same percentage of water as in the table on p. 212.	One ounce, water-free.
	Foot-tons.	Foot-tons.
Beef, uncooked, best quality (beefsteaks)	48.5	199
Meat, " as supplied to soldiers	57.8	243
Beef, " fattened	96.0	280
Meat, cooked	106.2	240
Corned beef (Chicago)	124.0	217
Salt beef	52.0	138
Salt pork	71.6	166
Fat pork	202.0	336
Dried bacon	292.3	346
Smoked ham	179.6	267
Horse flesh	46.4	189
White fish	44.3	209
Poultry	50.7	204
Bread	87.5	147
Wheat flour	123.6	146
Biscuit	173.3	189
Rice	126.5	141
Oatmeal	130.0	154
Maize	132.0	160
Macaroni	122.7	146
Millet	125.9	149
Arrow-root	116.4	138
Peas (dried)	118.9	151
Potatoes	33.0	141
Carrots	14.3	137
Cabbage	13.0	158
Butter	344.5	367
Eggs	67.3	265
Cheese	149.9	245
Milk (cow's), new	26.9	225
Cream	109.2	365
Skimmed milk	20.4	181
Sugar	126.4	128
Pemmican	270.1	293
Ale (Bass' bottled)	30.0	260
Stout (Guinness')	41.5	360

ments of the carnivora have been contrasted with the slow, dull action of domestic cattle; but, not to speak of the horse, whoever has seen the lightning movements of the wild antelope or cow, or even of the wild pig, which is herbivorous in many cases, can doubt that vegetable feeders can exert a movement even more rapid and more enduring than the tiger or the wolf? And the evidence in men is the same. In India, the ill-fed

people, on rice and a little millet or pea, may indeed show less power; but take the well-fed corn-eater, or even the well-fed rice and pea-eater, and he will show, when in training, no inferiority to the meat-eaters. An argument has been drawn from the complicated alimentary canal of the herbivora, but probably this is chiefly intended to digest the cellulose, and the digestion and absorption of albuminates may be as rapid as in other animals.

It appears from Dr. Beaumont's experiments that animal food is digested sooner than farinaceous, and possibly meat might therefore replace more quickly the wasted nitrogenous tissue than bread or peas; and it may be true, as asserted, that the change of tissue is more quick in meat-eaters, who require, therefore, more frequent supplies of food. Even this, however, seems not yet thoroughly proved.

It has been also supposed that there is a difference in the nutrition of even such nearly allied substances as wheat and barley, but the evidence is imperfect, and is perhaps dependent on differences in ease of digestion.

With respect to the fats, their differences of nutrition are probably dependent entirely on facility of digestion and absorption. The animal fats appear easier of absorption than the vegetable. Berthé[1] found that, in addition to the fat in his ordinary diet, he could absorb 30 grammes, or 1.059 ounce of cod-liver oil, butter, or other animal oil; in some instances $1\frac{3}{4}$ ounce were absorbed. Of vegetable oils only 20 grammes, or 0.7 ounce, were absorbed. When, in experiments with cod-liver oil, 40 grammes were taken, 31.5 were absorbed, 8.5 passed by the bowels; when 60 grammes were taken, 48 were absorbed and 12 passed. But when he took 60 grammes daily, the amount of fat in the fæces gradually increased, until 50 grammes daily passed off in that way. In the dog, however, Bischoff and Voit found that 250 and 300 grammes (8.8 and 10.5 ounces) of butter were easily absorbed. During the digestion of the fats they are, probably, in part decomposed; and the fatty acids, like the acids derived from the starch, must, to a certain extent, antagonize the introduction of alkali in the food.

The various carbo-hydrates are generally supposed to be of equal value. Starch requires a little more preparation by the digestive fluids than grape sugar, into which it appears first to pass; but the change is so rapid that it can hardly be made a point of difference between them. It is observable, however, that even when sugar is very cheap and accessible, it is not used to replace starch entirely; but this, perhaps, may be a matter of taste.

Sub-Section IV.—The Digestibility of Food.

In order that food shall be digested and absorbed, two conditions are necessary: the food must be in a fit state to be digested, and it must meet in the alimentary canal with the chemical and physical conditions which can digest and absorb it.

Fitness for digestibility depends partly on the original nature of the substance, as to hardness and cohesion, or chemical nature, and partly on the manner in which it can be altered by cooking. Tables of degree of digestibility have been formed by several writers, and especially by Dr. Beaumont, by direct experiment on Alexis St. Martin; but it must be re-

[1] Ludwig's Phys., Band ii., p. 668.

membered that these are merely approximative, as it is so difficult to keep the conditions of cooking equal.[1]

Rice, tripe, whipped eggs, sago, tapioca, barley, boiled milk, raw eggs, lamb, parsnips, roasted and baked potatoes, and fricasseed chicken, are the most easily digested substances in the order here given,—the rice disappearing from the stomach in one hour, and the fricasseed chicken in $2\frac{3}{4}$ hours. Beef, pork, mutton, oysters, butter, bread, veal, boiled and roasted fowls, are rather less digestible,—roast beef disappearing from the stomach in three hours, and roast fowl in four hours. Salt beef and pork disappeared in $4\frac{1}{4}$ hours.[2]

As a rule, Beaumont found animal food digested sooner than farinaceous, and in proportion to its minuteness of division and tenderness of fibre.

The admixture of the different classes of food aids digestibility ; thus fat taken with meat aids the digestion of the meat ; some of the accessory foods probably increase the outpour of saliva, gastric or enteric juice, etc.

The degree of fineness and division of food ; the amount of solidity and of trituration which should be left to the teeth, in order that the fluids of the mouth and salivary glands may flow out in due proportion ; the bulk of the food which should be taken at once, are points seemingly slight, but of real importance. There is another matter which appears to affect digestibility, viz., variety of food.

According to the best writers on diet, it is not enough to give the proximate dietetic substances in proper amount. Variety must be introduced into the food, and different substances of the same class must be alternately employed. It may appear singular that this should be necessary ; and certainly many men, and most animals, have perfect health on a very uniform diet. Yet, there appears no doubt of the good effect of variety, and its action is probably on primary digestion. Sameness cloys ; and with variety, more food is taken, and a larger amount of nutriment is introduced. It is impossible, with rations, to introduce any great variety of food ; but the same object appears to be secured by having a variety of cooking. In the case of children, especially, a great improvement in health takes place when variety of cooking is introduced ; and by this plan (among others), Dr. Balfour succeeded in marvellously improving the health of the boys in the Duke of York's School.

The internal conditions of abundance and proper composition of the alimentary fluids, and the action of the muscular fibres in moving the food, so that it shall be submitted to them, depend on the perfection of the nervous currents, the vigor of circulation, and the composition of the blood. Many of the digestive diseases the physican has to treat depend on alterations in these conditions, so that the food is only imperfectly digested. Experiments, by Plôsz, Maly, and Gyergyai, seem to show the value of converting the albuminates into peptones by artificial digestion, so as to aid the digestion of the sick.[3]

In framing diets, it is well to remember that almost every article has some portion which is more or less indigestible, but which is generally in-

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[1] The prepartion of food by cooking is so important a matter, that the art of cookery ought not to be considered as merely the domain of the gourmand. Health is greatly influenced by it, and it is really a subject to be practically studied by chemists and physiologists.

[2] An extended table is given in Cox's excellent edition of Combe's Physiology of Digestion, p. 123.

[3] Ueber Peptone, Archiv. für die Ges. Phys., Band ix., p. 323.

cluded in the calculation of its proximate or ultimate constituents. The proportion thus unutilized varies, but it ranges on an average from 5 to 10 per cent. Elaborate tables are given by Flügge [1] and Meinert.[2]

SECTION II.

DISEASES CONNECTED WITH FOOD.

So great is the influence of food on health, that some writers have reduced hygiene almost to a branch of dietetics. Happiness, as well as health, is considered to be insured or imperilled by a good or improper diet, and high moral considerations are supposed to be involved in the due performance of digestion. If there is some exaggeration in this, there is much truth; and doubtless, of all the agencies which affect nutrition, this is the most important.

The diseases connected with food form, probably, the most numerous order which proceeds from a single class of causes; and so important are they that a review of them is equivalent to a discussion on diseases of nutrition generally.

It is of course impossible to do more here than outline so large a topic.

Diseases may be produced by alterations (excess or deficiency) in quantity; by imperfect conditions of digestibility, and by special characters of quality.

SUB-SECTION I.—ALTERATIONS IN QUANTITY.

1. *Excess of Food.*—In some cases, food is taken in such excess, that it is not absorbed; it then undergoes chemical changes in the alimentary canal, and at last putrefies; quantities of gas (carbon dioxide, carburetted hydrogen, and hydrogen sulphide) are formed. As much as 30 ℔ of a half-putrid mass have been got rid of by purgatives.[3] Dyspepsia, constipation, and irritation, causing diarrhœa, which does not always empty the bowels, are produced. Sometimes some of the putrid substances are absorbed, as there are signs of evident poisoning of the blood, a febrile condition, torpor and heaviness, fætor of the breath, and sometimes possibly even jaundice. It was no doubt, cases of this kind which led to the routine practice of giving purgatives; and as this condition, in a moderate degree, is not uncommon, the use of purgatives will probably never be discontinued.

The excess of food may be absorbed. The amount of absorption of the different alimentary principles is not precisely known. Dogs can digest an immense quantity of meat, and especially if they are fed often; and not simply largely, once or twice a day. In men, also, much meat and albuminous matter can be digested,[4] though it is by no means uncommon,

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[1] Untersuchungen, etc., p. 424.

[2] Armee- und Volks-Ernährung, Berlin, 1880, vol. i., pp. 129–131, in which he quotes from Rubner (Zeitschr. f. Biologie, xv. u. xvi.) and Voit.

[3] A good case of this kind is recorded by Routh (Fæcal Fermentation, p. 19). Some convicts in Australia received from 7¼ to 7½ ℔s of food daily. Obstinate constipation, dyspepsia, diarrhœa, skin diseases, and ophthalmia were produced. Purgatives brought away large quantities of half-putrid masses.

[4] Jones's and especially Hammond's experiments, Experimental Researches, 1857, p. 20.

in large meat-eaters, to find much muscular fibre in the fæces. Still, enough can be taken, not merely to give a large excess of nitrogen, but even to supply carbon in sufficient quantity for the wants of the system.

There is certainly a limit to the digestion of starch (though sugar, however, is absorbed in large amount), as after a very large meal much starch passes unaltered. This is also the case with fat. But in all cases, habit probably much affects the degree of digestive power; and the continued use of certain articles of diet leads to an increased formation of the fluids which digest them.

When excess of albuminates continually passes into the system, congestions and enlargements of the liver, and probably other organs, and a general state of plethora, are produced. If exercise is not taken at the same time, there is a disproportion between the absorbed oxygen and the absorbed albuminates, which must lead to imperfect oxidation, and therefore to retention in the body of some substances, or to irritation of the eliminating organs by the passage through them of products less highly elaborated than those they are adapted to remove.

Although not completely proved, it is highly probable that gouty affections arise partly in this way, partly probably from the use of liquids which delay metamorphosis, and therefore lead to the same result as increased ingestion, and in some degree also from the use of indigestible articles of food.

Very often large meat-eaters are not gouty, and do not appear in any way over-fed. In this case either a great amount of exercise is taken, or, as is often the case in these persons, the meat is not absorbed, owing frequently to imperfect mastication.

A great excess of albuminates, without other food, produces, in a short time (five days—Hammond) marked febrile symptoms, malaise, and diarrhœa; and if persevered in, albumen appears in the urine. Ranke has attributed the depression especially to the effect of the salts of the meat.

Excess of starches and of fats delays the metamorphosis of the nitrogenous tissues and produces excess of fat. Sometimes acidity and flatulence are caused by the use of much starch. It is not understood if profounder diseases follow the excessive use of starches, unless decided corpulence is produced, when the muscular fibres of the heart and of many voluntary muscles lessen in size, and the consequences of enfeebled heart's action occur. When an excessive quantity of starch is used to replace albuminates, in physiological experiments, the condition becomes of course a complex one.

If an excess of starch be taken under any circumstances, much passes into the fæces, and the urine often becomes saccharine.

There may be also excess of food in a given time; that is, meals too frequently repeated, though the absolute quantity in twenty-four hours may not be too great.

2. *Deficiency of Food.*—The long catalogue of effects produced by famine is but too well known, and it is unnecessary to repeat it here. But the effects produced by deficiency in any one of the four great classes of aliments, the other classes being in normal amount, have not yet been perfectly studied.

The complete deprivation of albuminates, without lessening of the other classes, produces marked effects only after some days. In a strong man kept only on fat and starch, Dr. Parkes found full vigor preserved for five days; in a man in whom the amount of nitrogen was reduced one half, full vigor was retained for seven days. If the abstention be prolonged, however, there is eventually great loss of muscular strength, often mental debil-

ity, some feverish and dyspeptic symptoms. Then follow anæmia and great prostration. The elimination of nitrogen in the form of urea greatly lessens, though it never ceases, while the uric acid diminishes in a less degree. If starch be largely supplied, the weight of the body does not lessen for seven or eight days (Hammond).

If the deprivation of albuminates be less complete (70 to 100 grains of nitrogen being given daily), the body gradually lessens in activity, and passes into more or less of an adynamic condition, which predisposes to the attacks of all the specific diseases (especially of malarious affections and typhus), and of pneumonia, and modifies the course of some of these diseases as, for instance, of typhoid, which runs its course with less elevation of temperature than usual, and with less or with no excess of ureal excretion.

The deprivation of starches can be borne for a long time if fat be given, but if both fat and starch are excluded, though albuminates be supplied, illness is produced in a few days. Nor is it difficult to explain this: as albumen contains 53.3 per cent. of total carbon (of which about 49 per cent. is available for nutrition) and 15.5 per cent. of nitrogen, to supply 3,500 grains of carbon, no less than 1,139 grains of nitrogen must be introduced, a quantity three times as great as the system can easily assimilate, unless enormous exertion be taken, and then the quantity of carbon becomes insufficient.

Men can be fed on meat for a long time, as a good deal of fat is then introduced, and if the meat be fresh (and raw?), scurvy is not readily induced.

The deprivation of fat does not appear to be well borne, even if starches be given; but the exact effects are not known. The great remedial effects produced by giving fat in many of the diseases of obscure malnutrition, prove that the partial deprivation of fat is both more common and more serious than is supposed. In all the diets ordered for soldiers, prisoners, etc., the fat is greatly deficient in every country. The deprivation of the salts is also evidently attended with marked results, which are worthy of more attention than they have yet received.

Bad effects are also produced if the intervals between meals are too long; this is a matter in which there is great individual difference, and need not be further referred to.

Sub-Section II.—Conditions of Digestibility and Assimilation.

A great number of diseases are produced, not by alterations in quantity or by imperfections in the quality of the raw food, but by conditions of indigestibility, either dependent on physical or chemical conditions of the food itself, or of the digestive fluids. To some persons certain foods are indigestible at all times, or at particular times. Indigestibility leads to retention, and then to the results of retention, viz., chemical changes and putrefaction going on in the stomach and bowels under the influence of warmth, moisture, and air. Then irritation is produced, and dyspepsia, diarrhœa, or dysentery is caused.

Indigestibility extends, however, farther than this. There is some reason for thinking that the albuminates sometimes pass into the circulation less properly prepared than usual to undergo the action of the liver, and that they therefore produce irritation of that organ, and passing into the blood in some unassimilable state, produce irritation of the skin or kidneys. Sometimes, indeed, albumen appears in the urine, as if it had circulated like a foreign body in the blood. Such conditions are usually allied to some

evident error in primary digestion, but occasionally are not obviously accompanied by any gastric disorder. Whether there is any similar imperfection in the digestion of starch or fat is not at present known.

Sub-Section III.—Conditions of Quality.

Altered quality of what is otherwise good food produces a great number of diseases. Most of these are referred to under the headings of the different articles of food, and the subject is merely introduced here to complete the general sketch of the production of disease from food.

In inquiring, then, into the effect of food, the following appears to be the best order of procedure :—

1. Is the food excessive or deficient in quantity as a whole or in any of the primary classes of aliments?
2. Are the different articles digestible and assimilable, or, from some cause inherent in the food or proper to the individual, is there difficulty in primary digestion or want of proper assimilation?
3. Is the quality of the food altered either before or after cooking?

CHAPTER VI.

QUALITY, CHOICE, AND COOKING OF FOOD, AND DISEASES ATTRIBUTABLE TO IMPROPER QUALITY.

SECTION I.

MEAT.

The advantages of meat as a diet are—its large amount of nitrogenous substance, the union of this with much fat, the presence of important salts (viz., chloride of potassium, phosphate, and carbonate of potassium, or a salt forming carbonate in incineration), and iron. It is also easily cooked, and is very digestible; it is probably more easily assimilated than any vegetable, and there is a much more rapid metamorphosis of tissue in carnivorous animals than in vegetable feeders. Whether the use of large quantities of meat increases the bodily strength or the mental faculties more than other kinds of nitrogenous food is uncertain. The great disadvantage of meat is the want of starch.

The composition of fresh and salt meat has been already given; but the annexed table will supply further details:—

Composition of Fresh Beef. (*Moleschott—Mean of all the Continental Analyses.*)

Water	73.4
Soluble albumen and hæmatin	2.25
Insoluble albuminous substances	15.2
Gelatinous substances	3.3
Fat [1]	2.87
Extractive matters	1.38
Kreatin	0.068
Ash	1.6

It is worthy of remark that Stölzel[2] found 89 per cent. of carbonic acid in 100 of ash, which indicates probably lactic acid. Are the anti-scorbutic properties of fresh and raw (?) meat connected with this acid, and is it destroyed by cooking? More than one-third of the ash is composed of phosphoric acid. It is alkaline.

Beef, mutton, and pork form the chief meats eaten by the soldier.

In time of peace he only receives as fresh meat beef and mutton, and

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[1] The amount of fat in this analysis is certainly too low.

[2] Liebig's Annalen, Band lxxvii., p. 256.

more seldom pork; in time of war he has salt beef and salt pork.[1] The meat is supplied by contractors, or is, at some stations, furnished by the commissariat, who have their own slaughter-houses.

The medical officer may be called on to see the animals during life, or to examine the meat.

Sub-Section I.—Inspection of Animals.

Animals should be inspected twenty-four hours before being killed.[2]—In this country killing is done twenty-four or forty-eight hours before the meat is issued; in the tropics only ten or twelve hours previously.

Animals should be well grown, well nourished, and neither too young nor too old. The flesh of young animals is less rich in salts, fat, and syntonin, and also loses much weight (40 to 70 per cent.) in cooking.

Weight.—An ox should weigh not less than 600 ℔, and will range from this to 1,200 ℔. The French rules fix the minimum at 250 kilogrammes (=550 ℔ av.). The mean weight in France is 350 kilogrammes (=770 ℔ av.). A cow may weigh a few pounds less; a good fat cow will weigh from 700 to 740 ℔. A heifer should weigh 350 to 400 ℔. The French rules fix the minimum of the cow's weight at 160 kilogrammes (=352 ℔). The mean weight of cows in France is 230 kilogrammes (=506 ℔).

There are several methods of determining the weight; the one most commonly used in this country is to measure the length of the trunk from just in front of the scapulæ to the root of the tail, and the girth or circumference just behind the scapulæ; then multiply the square of girth by 0.08, and the product by the length, the dimensions in cubic feet are obtained; each cubic foot is supposed to weigh 42 ℔ avoirdupois. The formula is $(C^2 \times .08) \times L \times 42$. An ox or cow gives about 60 per cent. of meat, exclusive of the head, feet, liver, lungs, and spleen, etc.[3]

A full-grown sheep will weigh from 60 to 90 ℔, but the difference in different breeds is very great. It also yields about 60 per cent. of available food.

A full-grown pig weighs from 100 to 180 ℔, or more, and yields about 75 to 80 per cent. of available food.

Age.—The age of the ox and cow should be from three to eight years;[4] the age is told chiefly by the teeth, and less perfectly by the horns. The temporary teeth are in part through at birth, and all the incisors are

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[1] Professor Morgan of Dublin proposed the following plan of salting, which in certain cases might be usefully employed: Immediately after death the thorax is opened and a pipe inserted into the left ventricle; the pipe is connected, by an india-rubber tube, with a tank of brine placed at a few feet elevation, and through this the vessel is injected. After the blood has been driven out through the right auricle, the exit is closed, and the pressure forces the brine into the smallest ramifications of the vessels. The process is finished in ten to twenty minutes; the meat is then cut up, dried, if necessary, in a hot-air chamber, and packed in charcoal. The injected fluid is composed of 1 gallon of brine to the cwt., ¼ to ½ ℔ of nitre, 2 ℔s of sugar, a little spice, salt, and ½ oz. of phosphoric acid, which serves more completely to retain the albumen, and also adds a little phosphoric acid. The brine can be used hot. This is an excellent plan, but the meat is too salt.

[2] Every contract should have a clause giving officers the power of inspection.

[3] The animal is divided into carcass and offal; the former includes the whole of the skeleton (except the head and feet), with the muscles, membranes, vessels, and fat, and the kidneys and fat surrounding them. The offal includes the head, feet, skin, and all internal organs, except the kidneys.

[4] Dr. Pavy gives four years for the highest perfection of ox beef, on the authority of an "intelligent and experienced grazier."

through in twenty days ; the first, second, and third pairs of temporary molars are through in thirty days ; the teeth are grown large enough to touch each other by the sixth month ; they gradually wear and fall in eighteen months ; the fourth permanent molars are through at the fourth month ; the fifth at the fifteenth ; the sixth at two years. The temporary teeth begin to fall at twenty-one months, and are entirely replaced by the thirty-ninth to the forty-fifth month ; the order being—central pair of incisors gone at twenty-one months ; second pair of incisors at twenty-seven months ; first and second temporary molars at thirty months ; third temporary molars at thirty months to three years ; third and fourth temporary incisors at thirty-three months to three years. The development is quite complete at from five to six years. At that time the border of the incisors has been worn away a little below the level of the grinders. At six years the first grinders are beginning to wear, and are on a level with the incisors. At eight years the wear of the first grinders is very apparent. At ten or eleven years the used surfaces of the teeth begin to bear a square mark surrounded with a white line ; and this is pronounced on all the teeth by the twelfth year ; between the twelfth and fourteenth year this mark takes a round form.

The rings on the horns are less useful as guides. At ten or twelve months the first ring appears ; at twenty months to two years, the second ; at thirty to thirty-six months, the third ring ; at forty to forty-six months, the fourth ring ; at fifty-four to sixty months, the fifth ring, and so on. But at the fifth year the three first rings are indistinguishable, and at the eighth year all the rings. Besides, the dealers file the horns.

In the sheep, the temporary teeth begin to appear in the first week, and fill the mouth at three months ; they are gradually worn and fall about fifteen or eighteen months. The fourth permanent grinders appear at three months, and the fifth pair at twenty to twenty-seven months. A common rule is "two broad teeth every year." The wear of the teeth begins to be marked about six years.

The age of the pig is known up to three years by the teeth ; after that there is no certainty. The temporary teeth are complete in three or four months ; about the sixth month, the premolars, between the tusks and the first pair of molars, appear ; in six or ten months, the tusks and posterior incisors are replaced ; in twelve months to two years, the other incisors ; the four permanent molars appear at six months ; the fifth pair at ten months ; and the sixth and last molars at eighteen months.

Condition and Health.—There ought to be a proper amount of fat, which is best felt on the false ribs and the tuberosities of the ischia, and the line of the belly from the sternum to the pelvis ; the flesh should be tolerably firm and elastic ; the skin should be supple.

As showing health, we should look to the general ease of movements, the quick, bright eye ; the nasal mucous membrane red, moist, and healthy-looking ; the tongue not hanging ; the respiration regular, easy ; the expired air without odor ; the circulation tranquil ; the excreta natural in appearance.

When sick, the coat is rough or standing ; the nostrils dry or covered with foam ; the eyes heavy ; the tongue protruded ; the respiration difficult ; movements slow and difficult ; there may be diarrhœa ; or scanty or bloody urine, etc. In the cow the teats are hot.

The diseases of cattle which the medical officer should watch for are—

1. *Epidemic Pleuro-pneumonia* (or lung disease).—Not easily recognized at first, but with marked lung symptoms after a few days.

2. *Foot and Mouth Disease* (murrain, aphtha, or eczema epizootica).—At once recognized by the examination of the mouth, feet, and teats.
3. *Cattle Plague* (typhus contagiosus, Steppe disease, Rinderpest).—Recognized by the early prostration (hanging of head, drooping of ears), shivering, running from eyes, nose, and mouth, peculiar condition of tongue and lips, cessation of rumination, and then by abdominal pain, scouring, etc.
4. *Anthrax* (malignant pustule, carbuncular fever).—If boils and carbuncles form, they are at once recognized; if there is erysipelas, it is called black quarter, quarter ill, or blackleg (Erysipelas carbunculosum), and is easily seen. The peculiar organism, *Bacillus anthracis*, may be detected.
5. *Simple inflammatory affections* of the lungs, bronchitis, and simple pneumonia. All have obvious symptoms.
6. *Dropsical affections* from kidney or heart disease.
7. *Indigestion*, often combined with apoplectic symptoms.

A great number of other diseases attack cattle, which it is not necessary to enumerate. All the above are tolerably easily recognized. The presence of *Tænia mediocanellata* cannot, it would seem, be detected before death.

The diseases of sheep are similar to those of cattle; they suffer also in certain cases from splenic apoplexy or "braxy," which is considered by Professor Gamgee to be a kind of anthrax, and is said to kill 50 per cent. of all young sheep that die in Scotland; the animals have a "peculiar look, staggering gait, blood-shot eyes, rapid breathing, full and frequent pulse, scanty secretions, and great heat of the body."[1]

The small-pox in sheep (variola, ovina, *clavelée* of the French) is easily known by the flea-bitten appearance of the skin in the early stage, and by the rapid appearance of nodules or papulæ and vesicles.

The sheep is also subject to black quarter (Erysipelas carbunculosum); one limb is affected; and the limp of the animal, the fever, and the rapid swelling of the limb, are sufficient diagnostic marks.

The sheep, of course, may suffer from acute lung affection, scouring, red water (hæmaturia), and many other diseases. Of the chronic lung affections, one of the most important is the so-called "phthisis," which is produced by the ova of *Strongylus filaria*. This entozoon has not yet been found in the muscles, and the meat is said to be good. The rot in sheep (fluke disease) is caused by the presence of *Distoma hepaticum* in large numbers in the liver, and sometimes by other parasites. The principal symptoms are dulness, sluggishness, followed by rapid wasting and pallor of the mucous membrane, diarrhœa, yellowness of the eyes, falling of the hair, and dropsical swellings. The animal is supposed to take in *Cercaria* (the embryotic stage of *distoma*) from the herbage. The so-called "gid," "sturdy," or "turnsick," is caused by the development of *Cœnurus cerebralis* in the brain.

The pig is also attacked by anthrax in different forms, by typhoid, and by hog cholera.[2] The swelling in the first case, and the scouring, fever,

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[1] Fifth Report of the Medical Officer to the Privy Council, p. 222.

[2] Dr. Cobbold (Monthly Microscopical Journal, November, 1871) has pointed out that the pig is affected, both in America and Australia, with a large parasite (Stephanurus dentatus). This worm is found chiefly though not solely in the fat, and is at first free and then encysted; the cyst is large, and may be $1\frac{3}{4}$ inch in length and $\frac{1}{2}$ inch in diameter. The full-grown worm may be as much as $1\frac{1}{2}$ inch in length. Three to six

and prostration in the second, are sufficient diagnostic marks. In 1864, a severe fever of this kind, with or without scouring, prevailed among the pigs in London.

The so-called measle of the pig is caused by the presence in the muscle of *Cysticercus cellulosæ*. It is detected in the following way:—The "measle trier" throws the pig on its back, draws out and wipes the tongue, and looks and feels for the sublingual vesicles containing the *Cysticerci*. Sometimes a bit is cut out of the muscle under the tongue, and the *Cysticerci* are microscopically examined. A small harpoon can be used for this purpose, and gives little pain. Sometimes the *Cysticercus* can be seen on the conjunctiva, or on the folds of the anus. When the disease is far advanced, the animal is dull, the eyes heavy, appetite bad. These symptoms are, however, not peculiar; there is said to be sometimes tenderness in the groin (Grève), but, according to Delpech, this is very uncertain; a better sign is a certain amount of swelling of the shoulder, which causes a sort of constriction of the neck, and somewhat impedes the movements of the animals (Delpech). The presence of *Trichina spiralis* is indetectable before death, unless found in the muscles under the tongue.

Sub-Section II.—Inspection of Dead Meat.[1]

1. FRESH MEAT.

Meat should be inspected, in temperate climates, twenty-four hours after being killed; in the tropics, earlier.

The following points must be attended to:—

(*a*) *Quantity of Bone.*—In lean animals, the bone is relatively in too great proportion; taking the whole meat, 20 per cent. should be allowed.

(*b*) *Quantity and Character of the Fat.*—It should be sufficient, yet not excessive, else the relative proportion of albuminous food is too low; it should be firm, healthy-looking, not like jelly, or too yellow; without hemorrhage at any point. The kind of feeding has an effect on the color of the fat; some oil-cakes give a marked yellow color.

Professor Gamgee states that pigs fed on flesh have a peculiarly soft diffluent fat, and emit a strong odor from their bodies. The same authority tells us that the butchers will rub melted fat over the carcass of thin and diseased animals, to give the glossy look of health.

(*c*) *Condition of the Flesh.*—The muscles should be firm, and yet elastic; not tough; the pale moist muscle marks the young animal, the dark-colored the old one; the muscular fasciculi are larger and coarser

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eggs are found in the cyst, and the young worms migrate. During their migration, it has been surmised that they cause the "hog cholera."

[1] In the city of London, about 1 ton in 750 tons is condemned, but much escapes detection. Letheby (Lectures on Food, 2d edition, page 209) states that 700 tons of meat were destroyed in seven years; of this, 850,653 ℔ were diseased, 568,375 ℔ were putrid, and 193,782 ℔ were from animals which had died of accident or disease. "In the city of London, the practice is to condemn the flesh of animals infected with certain parasites, such as measles and flukes, etc., and of animals suffering from fever or acute inflammatory affections, or rinderpest, pleuro-pneumonia, and the fever of parturition, and of animals emaciated by lingering disease, and those which have died from accident or from natural causes, as well as all meat tainted with physic, or in a high state of putrefaction." (Ibid., p. 210.) It may be a question if meat should be condemned in some of these cases, as, for instance, pleuro-pneumonia. In India, meat with *Cysticerci* is now ordered to be received, but to be carefully cooked; but it would be very difficult to insure that proper cooking shall be always had recourse to.

in bulls than oxen. A deep purple tint is said to indicate that the animal has not been slaughtered, but has died with the blood in it (Letheby). When good meat is placed on a white plate, a little reddish juice frequently flows out after some hours. Good meat has a marbled appearance from the ramifications of little veins of fat among the muscles (Letheby). There should be no lividity on cutting across some of the muscles; the interior of the muscle should be of the same character, or a little paler; there should be no softening, mucilaginous fluid, or pus, in the intermuscular cellular tissue. This is an important point, which should be closely looked to. The intermuscular tissue becomes soft, and tears easily when stretched in commencing putrefaction.

The degree of freshness of meat in commencing putrefaction is judged of by the color, which becomes paler; by the odor, which becomes at an early stage different from the not unpleasant odor of fresh meat, and by the consistence. Afterward, the signs are marked; the odor is disagreeable, and the color begins to turn greenish.[1] It is a good plan to push a clean knife into the flesh up to its hilt. In good meat the resistance is uniform; in putrefying meat, some parts are softer than others. The smell of the knife is also a good test. *Cysticerci* and *Trichinæ* should be looked for.

(*d*) *Condition of the Marrow.*—In temperate climates the marrow of the hind legs is solid twenty-four hours after killing; it is of a light rosy red. If it is soft, brownish, or with black points, the animal has been sick, or putrefaction is commencing. The marrow of the fore legs is more diffluent; something like honey—of a light rosy red.

(*e*) *Condition of Lungs and Liver.*—Both should be looked at to detect *Strongylus filaria* in the lungs; *Distoma* in the liver; also for the presence of multiple abscesses.

(*f*) To detect *cattle plague*, the mouth, stomach, or intestines must be seen; no alterations have as yet been pointed out in the naked-eye appearance of the muscles, though under the microscope they are found to be degenerating like the muscles in human typhoid (Buchanan).

But meat cannot be fully judged of till it has been cooked, so as to see how much it loses in roasting or boiling; whether the fibres cook hard, etc.

In countries where there are goats, the attached foot of the sheep should be sent in for identification.

Decomposing sausages are difficult of detection until the smell alters. Artmann recommends mixing the sausage with a good deal of water, boiling and adding freshly prepared lime-water. Good sausages give only a faint not unpleasant, ammoniacal smell; bad sausages give a very offensive, peculiar ammoniacal odor.

Microscopic Examination of Meat.

In the flesh of cattle, or of the pig, *Cysticerci* may be found. They are generally visible to the naked eye as small round bodies; when placed under a microscope with low power, their real nature is seen; they are sometimes so numerous as to cause the flesh to crackle on section. The smallest *Cysticercus* noticed by Leuckart in the pig was about $\frac{4}{100}$ths of an inch long and $\frac{3}{100}$ths broad; but they are generally much larger, and will reach to $\frac{2}{10}$ths or $\frac{3}{10}$ths or $\frac{3}{4}$ths of an inch. In some countries they are

[1] In diseased meat there is a disagreeable odor, sometimes a smell of physic; very discoverable when the meat is chopped up and drenched with warm water.

extremely common in cattle, and have been a source of considerable trouble in Northwest India. *Cysticercus* of the ox produces in man *Tænia mediocanellata.* In sheep Cobbold has described a small *Cysticercus* with a double crown of hooks, 26 in number. He thinks that possibly a special *Tænia* may arise from this.[1] In diagnosing *Cysticerci* of pork the hooklets should always be seen.

Trichinæ may be present in the flesh of the pig ; if encapsuled they will be seen with the naked eye as small round specks ; but very often a microscope is necessary. A power of 50 to 100 diameters is sufficient. The best plan is to take a thin slice of flesh ; put it into liquor potassæ (1 part to 8 of water), and let it stand for a few minutes till the muscle becomes clear ; it must not be left too long, otherwise the *Trichinæ* will be destroyed. The white specks come out clearly, and the worm will be seen coiled up. If the capsule is too dense to allow the worm to be seen, a drop or two of weak hydrochloric acid should be added. If the meat is very fat, a little ether or benzine may be put on it in the first place. The parts most likely to be infected are said to be the muscular part of the diaphragm, the intercostal muscles, and the muscles of the eye and jaw.[2] In diagnosing *Trichinæ*, the coiled worm should be distinctly seen. *Stephanurus dentatus* in the pig has been already referred to.

The so-called *Psorospermia*, or Rainey's capsules, must not be mistaken for *Trichinæ*, nor indeed with care is error possible. These are little, almost transparent, bodies, found in the flesh of oxen, sheep, and pigs. They are in shape oval, spindle-shaped, or sometimes one end is pointed and the other rounded, or they are kidney-shaped. The investing membrane exhibits delicate markings, caused by a linear arrangement of minute, hair-like fibres, which Mr. Rainey[3] states increase in size as the animal gets older. They sometimes are pointed, and the appearance under a high power (1,000 diameters) is as if the investment consisted of very delicate, transparent, conical hairs, terminating in pointed process.[4] The contents of the cysts consist of granular matter, the granules or particles of which, when mature, are oval, and which adhere together, so as to form indistinct divisions of the entire mass. The length varies from $\frac{1}{300}$th to $\frac{1}{4}$th of an inch. They are usually narrow ; they lie within the sarcolemma, and appear often not to irritate the muscle.

Up to the present time no injurious effect has been known to be produced on men by these bodies, notwithstanding their enormous quantities in the flesh of domestic animals, nor have they been discovered in the muscles of men. But in pigs these bodies sometimes produce decided illness ; besides general signs of illness, there are two invariable symptoms, viz., paralysis of the hind legs, and a spotty or nodular eruption.[5] In sheep, they have been known to affect the muscle of the gullet, and produce abscesses, or what may be called so, viz., swellings sometimes as large as a nut, and containing a milky, purulent-looking fluid, with myriads of these capsules in it. Sheep affected in this way often die suddenly.[6]

It is by no means improbable that some effect on man may be hereafter discovered to be produced.

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[1] Surgeon-Major Oldham describes *Cysticercus tenuicollis* (from *Tænia marginata* of dog) as common in the sheep of the Punjab ; it has four suckers and a double coronet of 32 hooks.—Indian Medical Gazette, August, 1873.

[2] Lion, Comp. des Sanit.-Pol., p. 171.

[3] Phil. Trans., 1857.

[4] Beale, in Third Report of the Cattle Plague Commission, Appendix.

[5] Virchow's Archiv, Band xxxviii., p. 355.

[6] Leisering, in Virchow's Archiv, Band xxxvii., p. 431.

Some bodies, which have been also termed *Psorospermia*, found in the liver of the rabbit, and other parts, and in the liver of man, and which have been described by many observers in different terms,[1] may possibly be found in other animals, as they have been seen in the dog by Virchow. They are quite different from Rainey's corpuscles; they are oval or rounded bodies, at first with granular contents, and then with aggregations of granules into three or four rounded bodies, on which something like a nucleolus is seen. They have often been mistaken for pus-cells.

Some other bodies occur in the flesh of pigs, the nature of which is not yet known. Wiederhold[2] describes a case in which little white specks, with all the appearance at first of encapsuled *Trichinæ*, could not be proved to be so, and their real nature was quite obscure.

Virchow has described little concretions in the flesh of the pig, which seemed to be composed of guanin;[3] these were also at first taken for encapsuled *Trichinæ*.

Roloff[4] has noted little hard round nodules in the flesh of the pig, some seem very small, others as large as the head of a pin, with little prolongations running to the surrounding muscular fibres to which they are attached. On the outside of these bodies are bundles of fine hairs or needles, sometimes arranged in quite a feather-like form. The bodies have a great resemblance to the guanin bodies of Virchow, but the needles are not crystalline. Roloff puts the question if these bodies are of post-mortem origin.

It is hardly necessary to state that in cutting across meat, small bits of tendons or fascia, sometimes very like a little cyst, will be found; but common care will prevent a mistake.

2. SALT MEAT.

It is not at all easy to judge of salt meat, and the test of cooking must often be employed. The following points should be attended to:—

(*a*) *The salting has been well done, but the parts inferior.*—This is at once detected by taking out a good number of pieces; those at the bottom of the cask should be looked at, as well as those at the top.

(*b*) *The salting well done, and the parts good, but the meat old.*—Here the extreme hardness and toughness, and shrivelling of the meat, must guide us. It would be desirable to have the year of salting placed on the cask of salt beef or pork.

(*c*) *The salting well done, but the meat bad.*—If the meat has partially putrefied, no salting will entirely remove its softness; and even there may be putrefactive odor, or greenish color. A slight amount of decomposition is arrested by the salt, and is probably indetectable. *Cysticerci* are not killed by salting, and can be detected. Measly pigs are said to salt badly, but according to Gamgee this is not the case.

(*d*) *The salting badly done, either from haste or bad brine.*—In both cases signs of putrefaction can be detected; the meat is paler than it should be; often slightly greenish in color, and with a peculiar odor.

It should be remembered that brine is sometimes poisonous; this occurs in cases where the brine has been used several times; a large quantity of

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[1] Leuckart, Die Menschl. Paras, Band i., p. 740; Stieda, Virchow's Archiv, Band xxxii., p. 132; Roloff, Virchow's Archiv, Band xliii., p. 512.

[2] Virchow's Archiv, Band xxxiii., p. 549.

[3] Ibid., Band xxxv., 358.

[4] Ibid., Band xliii., p. 524.

animal substance passes into it, and appears to decompose. The special poisonous agent has not been isolated.

SUB-SECTION III.—DISEASES ARISING FROM ALTERED QUALITY OF MEAT.

A very considerable quantity of meat from diseased animals is brought into the market, but the amount is uncertain.

Instances are not at all uncommon in which persons, after partaking of butcher's meat, have been attacked with serious gastro-intestinal symptoms (vomiting, diarrhœa, and even cramp), followed in some cases by severe febrile symptoms; the whole complex of symptoms somewhat resembles cholera at first, and afterward typhoid fever. The meat has been often analyzed, for the purpose of detecting poison, but none has been found.[1] In the records of these cases, the kind of meat, the part used, and the origin from a diseased animal, are not stated, and, in some cases, it may be conjectured that the cooking, and not the meat, was in fault. Still, the instances are becoming numerous, and are increasing every day, as attention is directed to the subject. We should conclude from general principles, that as all diseases must affect the composition of flesh, and as the composition of our own bodies is inextricably blended with the composition of the substances we eat, it must be of the greatest importance for health to have these substances as pure as possible. Animal poisons may indeed be neutralized or destroyed by the processes of cooking and digestion, but the composition of muscle must exert an influence on the composition of our own nitrogenousus tises which no preparation or digestion can remove.

On looking through the literature of the subject, however, we find less evidence than might be expected. This is probably partly owing to imperfect observation, especially when we think for how long a time *Trichina* disease was overlooked.

1 *The flesh of healthy animals may produce Poisonous Symptoms.*—This is the case with certain kinds of fish, especially in the tropical seas. There is no evidence that the animal is diseased, and the flesh is not decomposed; it produces, however, violent symptoms of two kinds—gastro-intestinal irritation, and severe ataxic nervous symptoms, with great depression and algidity The little herring (*Clupea harengo minor*), the silver-fish (*Zeus gallus*), the pilchard, the white flat-fish, and several others, have been known to have these effects.[2] In some cases, though not in all, the poison is developed during the breeding time. Oysters (even when in season) and mussels have been known to produce similar symptoms, without any decomposition. The production of dyspepsia and nettle-rash in some persons from eating shell-fish need scarcely be mentioned.

Among the *Mammalia* the flesh of the pig sometimes causes diarrhœa —a fact noticed by Dr. Parkes in India, and often mentioned by others. The flesh is probably affected by the unwholesome garbage on which the pig feeds. Sometimes pork, not obviously diseased, has produced choleraic symptoms.[3] In none of these cases has the poison been isolated.

2. *The flesh of healthy animals when decomposing* is eaten sometimes

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[1] See Professor Gamgee's paper in the Fifth Report of the Medical Officer to the Privy Council, 1863, p. 287. He refers to cases noted by Maclagan, Taylor, Letheby, Dundas, Thomson, and Keith.

[2] A list of more than forty fishes, which are occasionally poisonous, is given by Pappenheim.—Hand. der Sanitats-Pol., Band i., p. 395.

[3] Kesteven cites a good case in which twelve persons were affected.—Med. Times and Gazette, March 5, 1864.

without danger ; but it occasionally gives rise to gastro-intestinal disorder —vomiting, diarrhœa, and great depression ; in some cases severe febrile symptoms occur, which are like typhus, on account of the great cerebral complication. Cooking does not appear entirely to check the decomposition.

It appears to be, in some cases, the acid fluids of cooked meat which promote this alteration.

Sausages and pork-pies, and even beefsteak-pies,[1] sometimes become poisonous from the formation of an as yet unknown substance, which is perhaps of a fatty nature. It is not trimethylamine, amylamine, or phenylamine—these are not poisonous (Schlossberger). The symptoms are severe intestinal irritation, followed rapidly by nervous oppression and collapse.[2] Neither salts nor spices hinder the production of this poison. M. Vandem Corput attributes the poisonous effects of sausages to a *fungus*, of the nature of *sarcina*, or what he terms *Sarcina botulina*.[3]

Dr. Ballard has reported two remarkable cases of poisoning by ham and hot baked pork. The first occurred at Welbeck in 1880, and the second at Nottingham in 1881. In both instances a number of persons who partook of the meat were taken ill, and some died. Dr. Klein examined the meat, and found it loaded with *Bacilli*, which were also found in the organs of the fatal cases. Guinea-pigs and mice, inoculated with the fluids of the body, died with pneumonia and peritonitic symptoms ; *Bacilli* were found in the organs.[4]

Oysters and shell-fish, when decomposing, produce also marked symptoms of the same kind. Rotten fish are used, however, by the Burmese, Siamese, and Chinese as a sort of condiment, without bad effects.

3. *The fresh and not decomposing flesh of diseased animals* causes in many cases injurious effects. A good deal of difference of opinion, however, exists on this point, and it would seem that a more careful inquiry is necessary. The probability is, that when attention is directed to the subject, the effect of diseased meat will be found to be more considerable than at present believed.[5] At the same time, we must not go beyond the facts as they are at present known to us, and at present certainly bad effects have been traced in only a few instances ; perhaps the heat of cooking is the safeguard.

(*a*) *Accidents.*—The flesh of animals killed on account of accidents may be eaten without injury.

(*b*) The flesh of *over-driven* animals is said by Professor Gamgee to contain a poison which often produces eczema on the skin of those who handle it ; and eating the flesh is said to "have been attended with bad effects."

(*c*) *Early Stage of Acute Inflammatory Disease.*—The meat is not ap-

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[1] I have seen very severe symptoms produced, diarrhœa and partial collapse, from eating beefsteak pie, which presented nothing unpleasant to the taste.—(F. de C.)

[2] A severe case of poisoning by liver sausages took place at Middelburg, in Holland, in March, 1874. Nearly 400 were attacked, and out of 343 reported cases, 6 died. The symptoms commenced a few hours after the sausages were eaten, consisting of nausea and vomiting, diarrhœa with offensive stools and abdominal pain and high fever. The symptoms, after apparent convalescence, recurred for several days, and at last became quite of an intermittent character. Chemical and microscopical examination failed to detect anything, except that there were quantities of the minutest organisms in the sausages. (Centralblatt für die Med. Wiss., 1875, No. 14, p. 219.)

[3] Quoted by Letheby, Chemical News, February, 1869.

[4] Report of the Medical Officer of the Local Government Board.

[5] Professor Gamgee says that one-fifth of the meat in London is more or less diseased.

parently altered, and it is said that some of the primest meat in the London market is taken from beasts in this condition ; it is not known to be injurious, but it has been recommended that the blood should be allowed entirely to flow out of the body, and should not be used in any way.

(*d*) *Chronic wasting Diseases—Phthisis, Dropsy, etc.*—The flesh is pale, cooks badly, and gives rise to sickness and diarrhœa. It also soon begins to decompose, and then causes very severe gastro-intestinal derangement. Grave doubts have recently arisen as to whether tuberculosis may not be communicable to man through the flesh of cattle suffering from that disease.[1]

(*e*) *Chronic Nervous Fevers.*—Same as above.

(*f*) *Epidemic Pleuro-pneumonia of Cattle.*—Much doubt exists as to the effect of this disease on the meat. It is hardly possible that the flesh should not be seriously altered in composition, but it seems certain that a large quantity is daily consumed without apparent injury. It is said, on the authority of Staff-Surgeon Nicolson and Assistant-Surgeon Frank, who made very careful inquiries on this point, that the Kaffirs ate their cattle, when destroyed by the epidemic lung disease which prevailed at the Cape a number of years ago, without injury. Dr. Livingstone, however, states that the use of such flesh produces carbuncle.

(*g*) *Anthrax and Malignant Pustule.*—Many of the older authors (Ramazzini, Lancisi, quoted by Lévy) mention facts tending to prove the danger of using the flesh of animals affected with malignant pustule. Chaussier also affirmed the same thing, but subsequently modified his opinion considerably. The apparent increase in the number of cases of malignant pustule in men has been ascribed to eating the flesh of animals with this disease, but it is quite as likely that inoculation may have taken place in other ways.

The evidence laid before the Belgian Academy of Medicine led them to believe the flesh of cattle affected with carbuncular fevers to be injurious, and it is not allowed to be sold.

It has been supposed that the outbreaks of boils, which have certainly become more prevalent of late years, are produced by meat of this kind, but the evidence is very imperfect.

Menschel[2] has recorded a case in which twenty-four persons were seized with malignant pustule, the majority after eating the flesh of beasts suffering from the disease, the others from direct inoculation. Those who ate the flesh were attacked in three to ten days ; those who were inoculated in three to six days. It is also stated that pigs fed on the flesh got the disease, and that a woman who ate some of the diseased pork was also attacked.

On the other hand, several old authors, and more lately Neffel,[3] assert that the Kirghises constantly eat horses and cattle (either killed or dying spontaneously) affected with malignant pustule, without injury.

Parent-Duchâtelet[4] quotes a case from Hamel (1737), in which a bull infected three persons who aided in killing it, and a surgeon who opened one of the tumors of a person affected ; yet, of more than 100 persons who ate the flesh roasted and boiled, no one experienced the slightest inconvenience, and Parent states that many other cases are known in literature.

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[1] Creighton, on Bovine Tuberculosis in Man ; also, Transactions of the International Medical Congress, 1881, vol. iv., p. 481.

[2] Preuss. Med. Zeit., 4th June, 1862 ; and Canstatt's Jahresb., 1862, Band iv., p. 257.

[3] Canstatt's Jahresb. for 1860, Band ii., p. 137.

[4] Tom. ii., p. 196.

Parent-Duchâtelet and Lévy[1] quote from Morand (1766) an instance in which two bulls communicated malignant pustule to two butchers by inoculation, yet the flesh of the animals was eaten at the "Invalides" without injury. But both these instances are of old date. Pappenheim[2] states (without giving special instances) that there are many cases in which no bad effect resulted from the cooked flesh of *charbon*—that the peasants of Posen eat such meat with perfect indifference, and believe it is harmless when boiled.

With regard especially to erysipelas carbunculosum, or black-quarter, as distinguished from malignant pustule (if it is to be so distinguished), Professor Gamgee[3] refers to cases of poisoning, and two deaths mentioned to him by Dr. Keith of Aberdeen, caused by eating an animal affected with black-quarter. He also notices an instance which occurred "a number of years ago in Dumfriesshire," when seventeen persons were more or less affected, and at least one died, and states that a number of cases have been related to him by different observers.

The discrepancy of evidence is so great as to lead to the conclusion, that the stage of the disease, or the part eaten, or the mode of cooking, must have great influence, and that a much more careful study than has yet been given to this subject is necessary to clear up these great variations of statement.

(*h*) *Splenic Apoplexy or Braxy of Sheep.*—Professor Simonds[4] states that pigs and dogs died in a few hours after eating the flesh of sheep dead of braxy. Professor Gamgee[5] affirms the same thing; but, on the other hand, Dr. M'Gregor states that dogs eat the meat with perfect impunity. The experiments at Alfort[6] have also shown that pigs, dogs, and fowls are not incommoded by this poison, which yet acts violently when swallowed by sheep, goats, or horses. So also Dr. Smith[7] states, that the shepherds in the Highlands of Scotland eat by preference braxy sheep, and are quite healthy. Dr. M'Gregor says that the flesh of braxy sheep is never cooked until it has been steeped for two months in brine, and then suspended for a time from the kitchen roof. It is preferred to ordinary salt mutton, because it has rather a flavor of game.

(*i*) *Small-pox of Sheep.*—The flesh has a peculiar nauseous smell, and is pale and moist. It produces sickness and diarrhœa, and sometimes febrile symptoms.

(*j*) *Foot-and-mouth Disease* (*Aphtha* (*or Eczema*) *epizootica*).—Lévy[8] states that at different times (1834, 1835, 1839) the aphthous disease has prevailed among cattle both at Paris and Lyons, without the sale of the meat being interrupted or giving rise to bad results. The milk of cows affected with foot-and-mouth disease has been supposed to cause vesicular affection of the mouth in men.[9] The evidence seems, however, very uncertain. The discharges from the mouth are constantly on the hands of the farm laborers, who are not very cleanly, and who must constantly convey them to their own mouths, and yet these discharges, so infectious to other cattle, produce no effect on them.

(*k*) *Cattle Plague* (*Rinderpest, Typhus contagiosus of the French*).—*A priori*, such flesh would be considered highly dangerous, and the Belgian

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[1] Traité d'Hygiène, 1879, tom. ii., p. 630.
[2] Handb. der Sanitats-Pol., Band i., p. 587.
[3] Fifth Report of Medical Officer to the Privy Council, p. 290.
[4] Agricultural Journal, No. 50, p. 232.
[5] Privy Council Report, 1863, p. 280.
[6] Lévy, t. ii., p. 631.
[7] Social Science Trans. for 1863, p. 559.
[8] Traité d'Hygiène, 1879, t. ii., p. 631.
[9] Jour. of the Epid. Soc., vol. i., p. 423.

Academy of Medicine so consider it; but there is some strong evidence on the other side. In Strasbourg and in Paris, in 1814, many of the beasts eaten in those cities for several months had rinderpest, and yet no ill consequences were traced. But it may be questioned whether they were looked for in that careful way they would be at the present day.[1] Some other evidence is stronger: Renault, the director of the Veterinary School at Alfort, made for several years after 1828 many experiments, and asserts that there is no danger from the *cooked* flesh of cattle, pigs, or sheep dead of any contagious disease ("quelle que soit la répugnance bien naturelle que puissent inspirer ces produits").[2] So also during the occurrence of the rinderpest in England (1865), large quantities of the meat of animals killed in all stages of the disease were eaten without ill effects. In Bohemia also, in 1863, the peasants dug up the animals dead with rinderpest, and ate them without bad results.[3]

(*l*) *Rabies* in the dog and cow produces no bad effects.[4]

(*m*) Diseases in the pig, like *scarlet fever* and *pig typhus*, have prevailed recently in London, and the flesh has been eaten. No injury has been proved.[5]

(*n*) *Cysticercus cellulosæ* of the pig produces *Tænia solium*, and that of the ox and cow *Tænia mediocanellata.* These entozoa often arise from eating the raw meat, but neither cooking nor salting are quite preservative, though they may lessen the danger. Smoking appears to kill *Cysticerci*, and so, according to Delpech, does a temperature of 212° Fahr. T. Lewis[6] found that a much lower temperature sufficed. When *Cysticerci* had been exposed for five minutes to a heat of 130° Fahr., he could detect no movements, and he considers that a temperature of from 135° to 140° F. for five minutes would certainly kill them. Lewis considers there is no danger if the cooking is well done, as the temperature of well-done meat is never below 150° F.

(*o*) *Trichina spiralis* in the pig gives rise to the curious *Trichina* disease caused by the wanderings of the young *Trichinæ.* The affection is highly febrile, resembling typhoid or even typhus, or acute tuberculosis, but attended with excessive pains in the limbs, and œdema.[7] Boils are also sometimes caused. The eating of raw trichiniferous pork is the chief cause, and the entozoon is not easily killed by cooking or salting. A temperature of 144° to 155° Fahr. kills free *Trichinæ*, but encapsuled *Trichinæ* may demand a greater heat (Fiedler). During cooking, a temperature which will coagulate albumen (150° to 155° Fahr.) renders *Trichinæ* incapable of propagation, or destroys them. As a practical rule, it may be said that if the interior of a piece of boiled or roasted pork retains much

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[1] The words of Coze (Parent-Duchâtelet, t. xi., p. 201) are, however, very strong. At Strasbourg he says: "Un millier de bœufs de grande taille, malades pour la plupart au plus haut degré, puisqu'un assez grand nombre ont été égorgés au moment où ils allaient expirer, a été consommé, pendant et après le blocus, et cet aliment n'a produit aucune maladie."

[2] Payen, Des Substances Alimentaires, pp. 30, 31.

[3] Evidence of Cattle Plague Commission, question 997, and other places.

[4] Parent-Duchâtelet, t. ii., p. 197, cites a case of seven mad cows being sold without injury to those who ate the flesh.

[5] Letheby, Chem. News, January 15, 1869.

[6] The Bladder Worms found in Beef and Pork, by T. R. Lewis, M.D., Calcutta, 1872.

[7] Aitken's Practice of Medicine, 7th edit., vol. i., p. 162. See also reports on Hygiene by the late Dr. Parkes, in the Army Medical Reports for 1860, 1861, 1862, and 1863, where references to most of the early cases will be found. See also Dr. Thudichum's treatise in Mr. Simon's Report to the Privy Council, 1864.

of the blood-red color of uncooked meat, the temperature has not been higher than 131° Fahr., and there is still danger. Intense cold and complete decomposition of the meat do not destroy *Trichinæ.*[1] Hot smoking, when thoroughly done, does destroy them (Leuckart); but the common kinds of smoking, when the heat is often low, do not touch *Trichinæ* (Küchenmeister).

(*p*) *Echinococcus Disease.*—It is well known that many persons will eat freely of, and even prefer, the liver of the sheep full of flukes. No direct evidence has been given of the production of disease from this cause, at least in this country. In Iceland, *Echinococcus* disease, which affects a large number of persons, is derived from sheep and cattle, who, in their turn, get the disease from *Tænia* of the dog (Leared and Krabbe).

(*q*) *Glanders* and *farcy* in horses do not appear to produce any injurious effects on their flesh when eaten as food. Parent-Duchâtelet[2] quotes two instances, in one of which 300 glandered horses were eaten without injury. In 1870, during the siege of Paris, large quantities of flesh from horses with farcy and glanders were eaten without injury.

(*r*) *Medicines*, especially *antimony*,[3] given to the animals in large quantities, have sometimes produced vomiting and diarrhœa. *Arsenic*, also, is occasionally given, and the flesh may contain enough arsenic to be dangerous.[4]

In time of peace, the duty of the army surgeon is simple. Under the terms of the contract, all sick beasts are necessarily excluded. Without reference, then, to any uncertain questions of hurtfulness, or the reverse, he must object to the use of the flesh of such animals. This is the safe and proper course.

But, in time of war, he may be placed in the dilemma of allowing such meat to be used, or of getting none at all. He should then allow the issue of the meat of all animals ill with inflammatory and contagious diseases, with the exception of small-pox, and perhaps splenic apoplexy in sheep. But it will be well to take the precautions—1st, Of bleeding the animals as thoroughly as possible; 2d, Of using only the muscles, and not the organs, as it is quite possible these may be more injurious than the muscles, though there are no decided facts on this point; and, 3d, Of seeing that the cooking is thoroughly done. But animals with small-pox, *Cysticerci*, and *Trichinæ*, should not be used. If dire necessity compels their use, then the employment of a great heat in a baker's oven and smoking, if it can be used, may lessen the danger. If such things can be got, it would be well to try the effect on the meat of antiseptics, especially of carbolic acid, which destroys low animal life of that kind with great certainty.

Sub-Section IV.—Cooking of Meat.

Boiling.—The loss of weight is about 20 to 30 per cent., sometimes as much as 40. If it is wished to retain as much as possible of the salts and

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[1] Carré (Comptes Rendus, xcv., p. 147) says that they are destroyed at 40° to 50° below zero of Centigrade (= 40° to 58° below zero of Fahrenheit).

[2] Hyg. Publ., t. ii., 194; see also Lévy, t. ii., p. 630.

[3] See a well-marked case cited by Pavy (A Treatise on Food and Dietetics, 2d ed., 1875, p. 160), as quoted by Gamgee, from the Central Zeitung für die gesammte Veterinärmedizin für 1854, where 107 persons were attacked after eating the flesh of an ox which had been treated with tartar-emetic previous to being slaughtered.

[4] Lévy, Traité d'Hygiène, 1879, t. ii., pp. 663–4; reference to experiments of Danger, Flandin, and Chatin.

soluble substances in the meat, the piece should be left large, and should be plunged into boiling water for five minutes to coagulate the albumen. After this the heat can scarcely be too low. The temperature of coagulation of the albuminoid substances differs in the different constituents; one kind of albumen coagulates at as low a heat as 86°, if the muscle serum be very acid; another albumen coagulates at 113° Fahr.; a large quantity of albumen coagulates at 167°. The hæmatoglobulin coagulates at 158° to 162°, below which temperature the meat will be underdone. If the temperature is kept above 170°, the muscular tissue shrinks, and becomes hard and indigestible. Liebig recommends a temperature of 158° to 160°. Most military cooks employ too great a heat: the meat is shrunken and hard. In boiling, ammonium sulphide is evolved, with odoriferous compounds, and an acid like acetic acid.

If it is desired to make good broth, the meat is cut small and put into cold water, and then warmed to 150° F.; beef gives the weakest broth. In a pint there are about 150 grains of organic matter, and 90 grains of salts. Mutton broth is a little stronger, and chicken broth strongest of all. About 82 per cent. of the salts of beef pass into the broth, viz., all the chlorides, and most of the phosphates.

Broth made without heat, by the addition of four drops of hydrochloric acid to a pint of water and a half pound of beef, is richer in soluble albumen. Lactic acid and chloride of potassium added together have the same effect. If rather more hydrochloric acid be used, but no salt, heat can be applied, and, if not higher than 130° Fahr., nearly 50 per cent. of the meat can be obtained in the broth.

Roasting.—The loss varies from 20 to 35 per cent.; in beef it is rather less than in mutton (Oesterlen). This loss is chiefly water; the proportion of carbon, hydrogen, nitrogen, and oxygen remaining the same (Playfair). Roasting should be slowly done; to retain the juices, the meat must be first subjected to an intense heat, and afterward cooked very slowly; the dry distillation forms aromatic products, which are in part volatilized; the fat is in part melted, and flows out with gelatin and altered extractive matters. The fat often, improperly, becomes the perquisite of the cook, and may be lost to the soldier. The loss in baking is nearly the same, or a little less.

Stewing.—This is virtually the same as roasting, only the meat is cut up, is continually moistened with its own juices, and is often mixed with vegetables. Like boiling and roasting, it should be done slowly, at a low heat; the loss then is about 20 per cent., and chiefly water.

In all cases there is one grand rule, viz., to cook the meat slowly, and with little heat, and, as far as possible, to let the loss be water only. The fault in military kitchens has been, that excessive heat is used. The meat is then often a sodden, tasteless mass, with hard, shrunken, and indigestible fibres. The thermometer will be found very useful, especially in showing cooks that the temperature is often much higher than they think. In the cooking of salt meat, the heat should be very slowly applied, and long continued; it is said that the addition of a little vinegar softens the hard sarcolemma, and it is certain that vinegar is an agreeable condiment to take with salt meat, and is probably very useful. It may be of importance to remember this in time of war.

In cutting up meat, there is a loss of about 5 per cent., and there is also a loss from bone, so that, all deductions being made, the soldier does not get more than 5 or 6 ounces of cooked meat out of 12 ounces.

The large quantity of flesh extract contained in the brine can be ob-

tained by dialysis; from two gallons of brine a fluid has been obtained, which, on evaporation, yielded 1 lb of extract.[1]

Sub-Section V.—Preservation of Meat.

Meat may be kept for some time by simply heating the outside very strongly, so as to coagulate the albumen; or by placing it in a close vessel, in which sulphur is burnt, or by covering the surface with charcoal, or strong acetic acid, or calcium disulphite, or weak carbolic acid. Injections of alum and aluminium chloride through the vessels will preserve it for a long time; water should be injected first, and then the solution. Even common salt injected in the same way will keep it for some time. So also will free exposure to pure air; charcoal thrown over it, and suspended also in the air; or the meat being cut into smaller portions, and placed in a large vessel, heat should be applied, and, while hot, the mouth of the vessel should be closed tightly with well washed and dried cotton-wool; the air is filtered, and partially freed from germs. The application of sugar to the surface is also a good plan. Cold is a great preservative of meat; in ice it can be preserved for an unlimited period, and the supposed rapid decomposition after thawing seems to have been exaggerated.[2] Fresh meat is now largely imported from America and Australia, by being kept in refrigerated chambers.

Plans of this kind may be useful to medical officers under two circumstances, viz., on board ship, and in sieges, when it is of importance to preserve every portion of food as long as possible. The covering the whole surface with powdered charcoal is perhaps as convenient as any plan. A coating of paraffin, and many other plans of excluding air, are also used.

Meat is also preserved in tin cases, either simply by the complete exclusion of air (Appert's process), or by partly excluding air, and destroying the oxygen of the remaining part by sodium sulphite (M'Call's process). It is not necessary to raise the heat so high in this case, and the meat is less sapid. Meat prepared in either way has, it is said, given rise to diarrhœa, but this is simply from bad preparation; when well manufactured it has not this effect.

Meat is also preserved by drawing off the air from the case, and substituting nitrogen and a little sulphur dioxide (Jones and Trevithick's patent), or the air can be heated to 400° or 500° so as to kill all germs (Pasteur), and then allowed to flow into an exhausted flask.[3]

Various other plans have been proposed, such as the use of antiseptics, carbolic acid (?), borax, boracic acid, salicylic acid, etc.; but it is doubtful if any of them should be adopted without further inquiry, as it is by no means certain that such agents might not exercise a harmful influence on the human economy.[4]

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[1] Whitelaw, Chemical News, March, 1864.

[2] Bonley, Comptes Rendus, xcv., p. 147.

[3] Dr. Letheby's Cantor Lectures on Food, delivered before the Society of Arts in 1860, 2d edition, 1872, give a good account of some of the patents for the preservation of meat. See also Meinert, Armee- und Volks-Ernährung, Berlin, 1880, vol. ii., p. 265; also Renk, Conservirung von Nahrungsmitteln, Deutsche Vierteljahrschr. f. öff. Gesundheitspfl., Band xiii., Heft 1.

[4] A substance called Glacialin has been recommended: this consists of borax, boracic acid, sugar, and glycerin. The two latter are preservative of themselves, so that the addition of the former seems superfluous. The mixture of borates with glycerin has also been recommended by Le Bon in France and Barff in England.

SECTION II.

WHEAT.

Advantages as an Article of Diet.—It is poor in water and rich in solids, therefore very nutritious in small bulk ; when the two outer coats are separated, the whole grain is digestible. The nitrogenous substances are large and varied,[1] consisting of soluble albumen (1 to 2 per cent.) and gluten (8 to 12 per cent.), which itself consists of four substances, which are named by Ritthausen,[2] glutin-casein, gliadin (or vegetable gelatin), glutin-fibrin, and mucedin. The starchy substances (starch, dextrin, sugar) are large, 60 to 70 per cent., and are easily digested ; and, according to Mége-Mouriès, a nitrogenous substance (cerealin) is contained in the internal envelope, which, like diastase, acts energetically in transforming starch into dextrin, sugar, and lactic acid. Some consider this cerealin to be merely a form of diastase. Cholestrin is found in wheat, but in very small quantity (Ritthausen). The salts are chiefly phosphates of potash and magnesia.

Disadvantages.—It is deficient in fat, and in vegetable salts which may form carbonates in the system.

As usually prepared, the grain is separated into flour and bran ; the mean being 80 parts of flour, 16 of bran, and 4 of loss. The flour is itself divided into best or superfine, seconds or middlings, pollards or thirds or bran flour. In different districts different names are used. The wheats of commerce are named from color or consistence (hard or soft ; white or red) ; the hard wheat contains less water, less starch, and more gluten than the soft wheat.

SUB-SECTION I.—WHEAT GRAINS.

The medical officer will seldom be called on to examine wheat grains, but if so, the following points should be attended to. The grains should be well filled out, of not too dark a color ; the furrow should not be too deep ; there should be no smell, no discoloration, and no evidence of insects or *fungi.* The heavier the weight the better. In the Belgian army the minimum weight is 77 kilogrammes the hectolitre.[3] In England, good wheat weighs 60 ℔ to the bushel ; light wheat 58 ℔ or even 50 ℔. *Fungi,* if present, will be found at the roots of the hairs, and if in small amount, are only microscopic. If in large amount they cause the diseases known by the name of rust, bunt or smut, or dust brand ; they are owing to species of *Uredo* and *Puccinia.* If any grains are seen pierced with a hole, and on examination are found to be a mere shell, with all the starch gone, this is owing to the weevil, and the little insect can itself be found readily enough if a handful of wheat be taken and spread over a large plate. The weevil can hardly escape being seen. *Acarus farinæ* may also prey on the wheat grain, but cannot be seen without a microscope.

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[1] These reach 14 to 15 per cent., especially in the hard wheats of Italy and Sicily, which are used for macaroni (Letheby).

[2] Die Eiweisskörper der Getreidearten, von Dr. H. Ritthausen, 1872.

[3] Squillier, Des Subsist. Mil., p. 37.

SUB-SECTION II.—FLOUR.[1]

Almost all the bran is separated from the finest flour; it has been a question whether this is desirable, as the bran contains nitrogenous matter—as much sometimes as 15 per cent., with 3.5 per cent. of fat, and 5.7 per cent. of salts. But if the bran is used, it seems probable that much is left undigested, and all the nutriment which is contained in it is not extracted. A plan has been employed by Mége-Mouriès, which seems to save all the most valuable parts of the bran; the two or three outer and highly siliceous envelopes of the wheat are detached, and the fourth or internal envelope is left. Several plans of decorticating wheat have been proposed, but none of them at present have superseded the old system of grinding.

If the whole wheat is used, it should be ground very fine, as the harder envelopes are very irritating, and it is well to remember that for sick persons with any bowel complaints bread must be used entirely without bran. Dysenteries have been found most intractable, merely from attention not being directed to this simple point. It is all the more necessary to insist upon this, as whole meal bread has been much recommended and used of late.

Examination of Flour for Quality and Adulteration.

Flour should be examined physically, microscopically, chemically, and practically by making bread.

The quality is best determined by chemical examination; adulterations by the microscope.

Physical Examination.

Sight.—The starch should be quite white, or with the very slightest tinge of yellow; any decided yellow indicates commencing changes; the amount of bran should not be great.

Touch.—There should be no lumps, or if there are, they should at once break down on slight pressure; there must be no grittiness, which shows that the starch grains are changing, and adhering too strongly to each other, and will give an acid bread. There should, however, be a certain amount of adhesion when a handful of flour is compressed, and if thrown

[1] The following is given by Peligot (mean of 14 analyses), as the relative composition of flour and bran. The analyses of Von Bibra (Die Getreidearten und das Brod, 1860) agree very closely with it.

Wheat Flour and Bran.	In 100 parts, Flour.	Bran.
Water	14.0	10.3
Fatty matters	1.2	2.82
Nitrogenous substances insoluble in water (gluten)	12.8	10.84
Nitrogenous substances soluble in water (albumen)	1.8	1.64
Non-nitrogenous soluble substances (dextrin, sugar)	7.2	5.8
Starch	59.7	22.62
Cellulose	1.7	43.98[2]
Salts	1.6	2.52

[2] This is, however, the cellulose of the entire grain, both of the husk and the interior of the grain. Potash, phosphoric acid, and magnesia are the principal ingredients of the salts; the earthy phosphates are especially combined, and in definite proportions, with the albuminates (Mayer), and also the gummy matter (Bibra). The alkaline phosphates are free. The bran contains much silica. Oudemans places the cellulose lower (25 to 30 per cent.), and the salts higher (4 to 6 per cent.).

against a wall or board some of the flour should adhere. When made into a paste with water, the dough must be coherent, and draw out easily into strings.

Taste.—The taste must not be acid, though the best flour is slightly acid to test-paper. An acid taste, showing lactic or acetic acid, is sure to give an acid bread.

Smell.—There must be no smell of fermentation or mouldiness.

Age of flour is shown by color, grittiness, and acidity.

Chemical Examination.

It is seldom that a medical officer will be able to go through a complete examination, but he should always determine the following points:—

1. *Amount of Water.*—Weigh 1 gramme, spread it out on a dish, and dry either by a water bath or in a hot-air bath or oven, the temperature not being allowed to go above 212°. The flour must not be at all burnt or much darkened in color. Weigh directly the flour is cold; the loss is the percentage of water.

The range of water is from 10 (in the best dried flours) to 18 in the worst. The more water the greater liability of change in the flour, and, of course, the less is the amount of nutriment purchased in a given weight. If, then, the water be over 18 per cent., the flour should be rejected; if over 16, it should be unfavorably spoken of.

2. *Amount of Gluten.*—Weigh 10 grammes, and mix, by means of a glass rod, with a little water, so as to make a well-mixed dough; let it stand for quarter of an hour in an evaporating dish; then pour a little water on it; work it about with the rod, and carefully wash off the starch; pour off from time to time the starch water into another vessel. After a time, the gluten becomes so coherent, that it may be taken in the fingers and worked about in water, the water being from time to time poured off till it comes off quite clear. If there is not time to dry the gluten, then weigh; the dry gluten is rather more than one-third the weight of the moist; 1 to 2.9 is the usual proportion; therefore divide the weight of the moist gluten by 2.9. If there be time, dry the gluten thoroughly, and weigh it. This is best done by spreading it out on a crucible lid and drying it in the bath. The dry gluten ranges from 8 to 12 per cent.; flour should be rejected in which it falls below 8. If there is much bran, it often apparently increases the amount of gluten by adhering to it, and should be separated if possible; in fact, the gluten, as thus obtained, is never pure, but always contains some bran, starch, and fat. The gluten should be able to be drawn out into long threads; the more extensible it is the better. It is always well to make two determinations of gluten, especially if there is any disputed question of quality.[1]

3. *Amount of Ash.*—Take 10 grammes,[2] put into a porcelain or platinum crucible, and incinerate to white ash. Weigh. The ash should not be more than 2 per cent., or probably some mineral substances have been added; it should not be less than .8, or the flour is too poor in salts.

The incineration of the flour requires a crucible and gas. It is difficult to do it over a spirit lamp, as it takes a long time. A small charcoal fire is probably the best plan when gas appliances are wanting.

[1] Mr. Wanklyn has proposed to utilize the albuminoid ammonia process for determining gluten, reckoning that 100 parts of flour yield 1.2 of ammonia.

[2] If only a small crucible be employed a smaller quantity should be taken, as it is difficult to incinerate; with a moderately good balance, 2 or 3 grammes may be used.

If the ash be more than 2 per cent., add hydrochloric acid, and see if there be effervescence (magnesium or calcium carbonate). Dissolve, and test with oxalate of ammonium, and then for magnesia, in the same way as in water. As flour contains both lime and magnesia, to prove adulteration, the precise amount of lime and magnesia must be determined by weighing the incinerated calcium oxalate, or the magnesium pyrophosphate.

If there is no effervescence, add water, and test for sulphuric acid and lime, to see if calcium sulphate (plaster of Paris) has been added. In normal flour the amount of sulphuric acid is very small.

Notice, also, if the ash be red (from iron). If clay has been added, it will be left undissolved by acids and water.

If magnesium carbonate has been added, the ash is light, and porous and bulky (Hassall).

An easy mode of detecting large quantities of added mineral substances is given by Redtenbacher ; the flour is strongly shaken with chloroform ; the flour floats, while all foreign mineral substances fall. This is a very useful test.[1]

If the water be small, the gluten large, and the salts in good quantity, the flour is good, supposing nothing is detected on microscopical examination. But in all cases it is well, if time can be spared, to have a loaf made.

Practical Test by Baking.—Make a loaf, and see if it is acid when fresh, and how soon it becomes so ; if the color is good, and the rising satisfactory. Old and changing flour does not rise well, gives a yellowish color to the bread, and speedily becomes acid. Excess of acidity can be detected by holding a piece of bread in the mouth for some time, as well as by test-paper.

Test for Ergot.—There is no very good test for ergot when it is ground up with the flour. Laneau's plan is to make a paste with a weak alkaline solution ; to add dilute nitric acid to slight excess, and then alkali to neutralization ; a violet-red color is said to be given if ergot is present, which becomes rosy-red when more nitric acid is added, and violet when alkali is added.

Wittstein considers this method imperfect, and prefers trusting to the peculiar odor of propylamine (herring-like smell), developed by liquor potassæ in ergoted flour.

Microscopical Examination.

This is especially directed to determine the relative amount of flour and bran, the presence of *fungi* or *acari*, or the fact of adulteration by other grains.

In examining wheat, or any other cereal grains, it is necessary to prepare them beforehand by soaking for some time in water. It will then be found easy to demonstrate the different structures. By means of a needle and a pair of fine forceps the different coats can be removed *seriatim*, sometimes quite separately, but generally more or less in combination. The only one that presents any difficulty is the third coat of wheat or barley,

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[1] The remaining ingredients can be determined, if necessary, from the starch water, but it is seldom necessary to do so. Allow the starch to subside, pour off the fluid, and wash the starch by decantation, then dry and weigh ; take all the water and washings, evaporate to a small bulk, add a little nitric acid, and boil ; albumen is thrown down ; collect, wash, and weigh. Evaporate the whole of the remainder to dryness, and weigh (mixed dextrin and sugar).

but generally it can be found accompanying the second or fourth coats. In In the case of barley, the proper external envelope of the grain sometimes adheres to the interior of the husk, where it ought to be looked for in the event of its not being on the surface of the grain itself. After examining the separate coats, sections may be made of the whole grain, so as to see

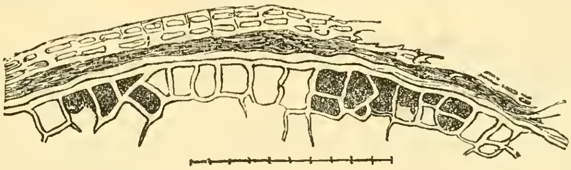

FIG. 23.—Transverse Section of Envelopes of Wheat. Scale 1,000th of an inch.

the structures *in situ*. The hairs are generally found in a bunch at the end of the grain. The starch grains are best demonstrated by picking out a little from the centre of the grain; mixed glycerin and water form the best medium for demonstration.

Structure of the Wheat Grain.—There are four envelopes (some authors make three, others five or six—the outer coat being divided into two or

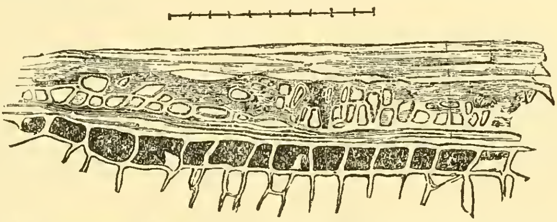

FIG. 24.—Envelopes of Wheat (longitudinal section). Scale 1,000th of an inch.

three) surrounding a fine and very loose areolar tissue of cellulose filled with starch grains.

Envelopes of Wheat.—The drawings show the coats *in situ*, cut transversely and longitudinally, also the separate coats. The outer coat is made up of

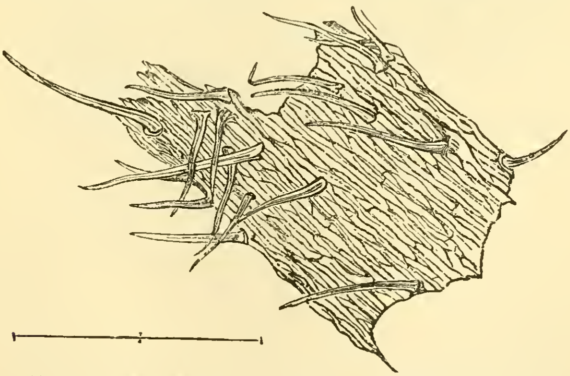

FIG. 25.—Outer Coat and Hairs of Wheat. Scale 100th of an inch.

two or three layers of long cells, with slightly beaded walls, running in the direction of the axis of the grain. The septa are straight or oblique, and, as will be seen, the cells differ in length and breadth. The size can be

taken by the scale. The hairs are attached to this coat, and are prolongations, in fact, of the cells. In the finest flour the hairs and bits of this coat (as well of the other coats) can be found.

The second coat, counting from without, is composed of a layer of shorter cells, more regular in size, with slightly rounded ends and beaded

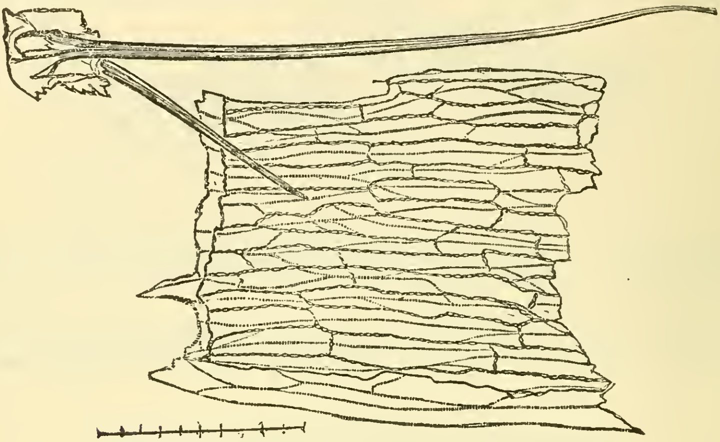

FIG. 26.—Outer Coat and Hairs of Wheat. Scale 1,000th of an inch.

walls, and lying at right angles to the first coat, or across the axis of the grain. It is impossible to mistake it. The third coat is a delicate diaphanous, almost hyaline membrane, so fine that its existence was formerly doubted. Dr. Maddox, however, has distinctly shown it to have faint lines

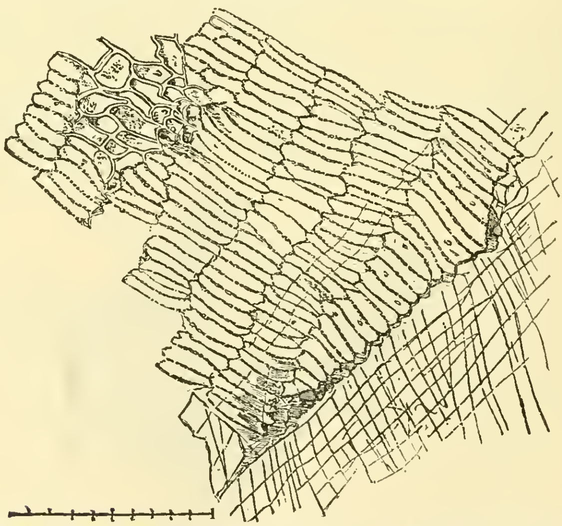

FIG. 27.—Second and Third Envelopes of Wheat. Scale 1,000th of an inch.

crossing each other diagonally as seen in the drawing, which may be cells. With a little care, it is very easily demonstrated. In the transverse section of the envelope it appears as a thin white line. Internal, again, to this

coat what appears to be another coat can sometimes be made out; it is a very fine membrane, marked with widely separated curved lines, which look like the outlines of large round or oval cells. The internal or fourth coat, as it is usually called, is composed of one or two layers (in places) of rounded or squarish cells filled with a dark substance which can be emptied from the cells. When the cells are empty, they have a remote re-

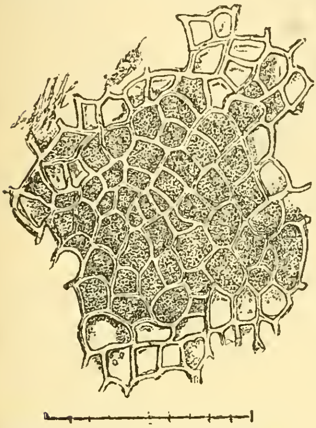

FIG. 28.—Fourth Envelope of Wheat. Scale 1,000th of an inch.

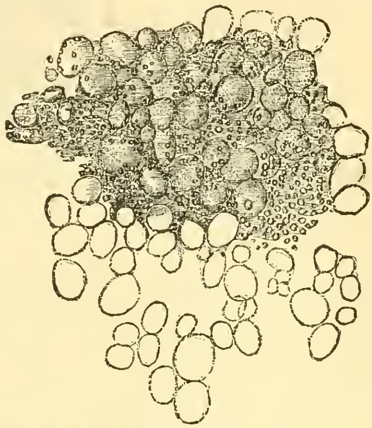

FIG. 29.—Fresh Starch Grains of Wheat (moistened). ×360.

semblance to the areolar tissue of the leguminosæ, and there is little doubt that from this cause adulteration with pea or bean has been sometimes improperly asserted.

The *starch grains* of wheat are very variable in size, the smallest being almost mere points, the largest $\frac{1}{1000}$th of an inch in diameter or larger. In shape the smallest are round; the largest round, oval, or lenticular. It has been well noticed by Hassall that there is often a singular want of

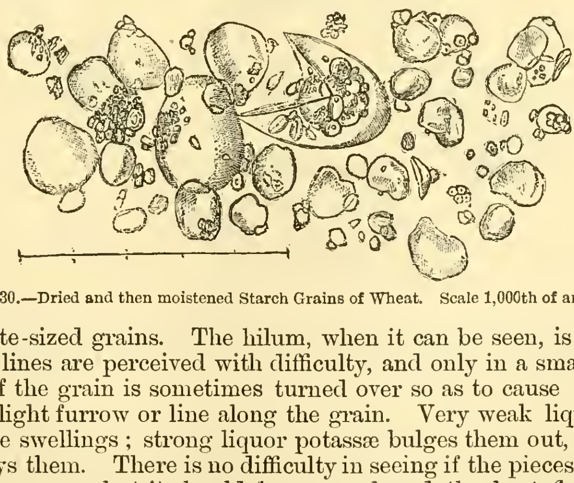

FIG. 30.—Dried and then moistened Starch Grains of Wheat. Scale 1,000th of an inch.

intermediate-sized grains. The hilum, when it can be seen, is central, the concentric lines are perceived with difficulty, and only in a small number; the edge of the grain is sometimes turned over so as to cause the appearance of a slight furrow or line along the grain. Very weak liquor potassæ causes little swellings; strong liquor potassæ bulges them out, and eventually destroys them. There is no difficulty in seeing if the pieces of envelope are too numerous, but it should be remembered the best flour contains some.

Diseases of Flour.

Fungi.—Several fungi are found in wheat-flour. The most common fungus is a species of *Puccinia.* It is easily recognized by its round dark sporangia, which are either contoured with a double line, or are covered

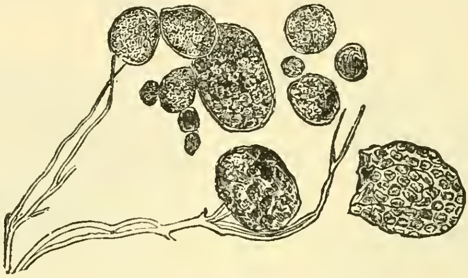

Fig. 31.—Diseased Flour (*Puccinia*).

with little projections. It is said not to be injurious by some, but this is very doubtful. The symptoms have not been well described.

The smut, or caries, is also a species of *Puccinia ;* has large sporules, and gives a disagreeable smell to the flour, and a bluish color to the bread. It is said to produce diarrhœa.

Acarus.—*Acarus farinæ* is by no means uncommon in inferior flour,

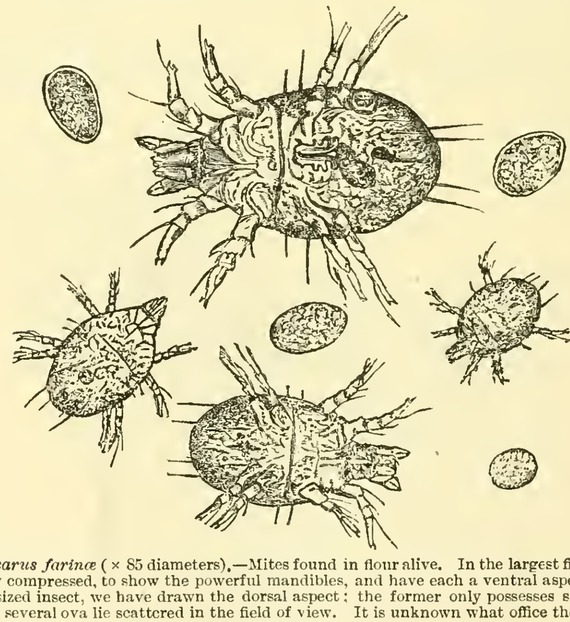

Fig. 32.—*Acarus farinæ* (× 85 diameters).—Mites found in flour alive. In the largest figures, the insects are considerably compressed, to show the powerful mandibles, and have each a ventral aspect. In the smallest and middle-sized insect, we have drawn the dorsal aspect; the former only possesses six legs, as before the first moult; several ova lie scattered in the field of view. It is unknown what office the capsular organs fulfil. They are well seen on each side of the largest figure.

especially if it is damp. It does not necessarily indicate that leguminous seeds are present, as stated. It is no doubt introduced from the grain in the mill, as it has been found adhering to the grain itself. It is at once recognized. Portions of the skin are also sometimes found.

Vibriones.—These form for the most part in flour which has gone to extreme decomposition, and which is moist and becoming discolored. They cannot be mistaken.

The presence of *Acari* always shows that the flour is beginning to change. A single *acarus* may occasionally be found in good flour, but even one should be looked on with suspicion, and the flour should be afterward frequently examined to see if they are increasing.

Weevil (*Calandra granaria*).—The weevil is of course at once detected. It is by no means so common in flour as in corn.

FIG. 33.
Weevil. Natural size.

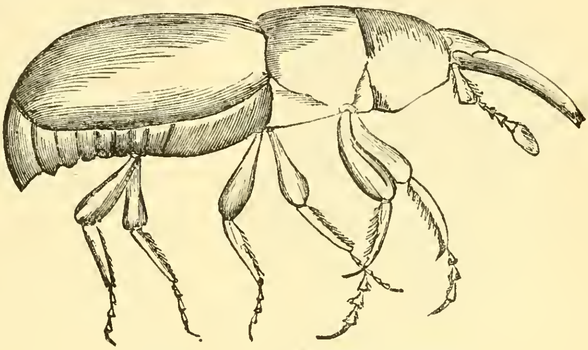

FIG. 34.—Weevil. Magnified 12 diameters.

Ephestia.—The larva of the moth, which feeds on cocoa (*Ephestia elutella*), has sometimes caused great ravages in flour and in biscuits. At Cork and Gibraltar many tons of biscuit have been rendered useless by this larva, which appears to have been introduced from the cocoa stored for the fleet.[1]

Adulterations of Wheat-Flour.

At present there is very little adulteration of wheat-flour in this country, but with rising prices the case might be different. Abroad, adulteration is probably more common, and the medical officer must be prepared to investigate the point.

The chief adulterations are by the flour of other grains, viz. :—

Barley,	Rice,	in some countries,
Potato,	Buckwheat,	
Beans and peas,	Millet,	
Maize,	Linseed,	
Oat,	Melampyrum,	
Rye,	Lolium,	

and other grains noticed farther on. All these are easily recognized by the microscope.

Other adulterations are by mineral substances, viz. :—

Alum,	Powdered flint,
Gypsum,	Calcium and magnesium carbonate.
Clay,	

These are best detected by chemical examination.

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[1] Professor Huxley has kindly given these interesting details. The larva of the *Ephestia elutella* (or "chocolate moth") is small, and is never more than half an inch long. The female moths fly at night in swarms, and lay their eggs on the biscuits or

Detection of Barley.—This is not easy, but can, with care, be often done.

The envelopes of barley are the same in number as those of wheat, but they are more delicate. The outer coat has three layers of cells ; the walls of the external layer are beautifully waved, but not beaded ; the cells are smaller than those of the outer coat of wheat. The second coat disposed at right angles to the first, as in wheat, is like the second coat of wheat, except in being more delicate and not beaded. The third is hyaline and transparent, as in wheat. The fourth has the cells similar in shape to the corresponding wheat coat, but they are very much smaller, as may be seen on reference to the scale, and there are two, or often three, layers.

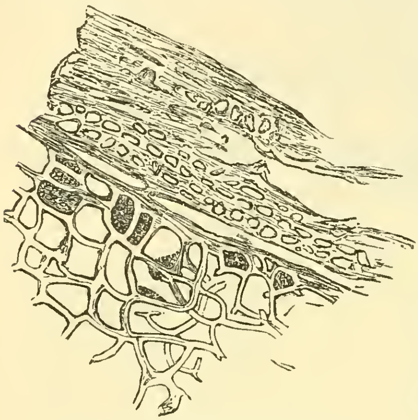

FIG. 35.—Barley (longitudinal section). Scale is the same as that of the Starch-grains.

The starch-grains of barley are very like the wheat, with a central hilum and obscure marking, but are on the whole smaller ; some have thickened edges, instead of the thin edges of the wheat-starch grain, but it is very difficult and sometimes impossible to distinguish them. It is therefore specially to the envelopes that we must attend.

Detection of Potato Starch.—This is a matter of no difficulty ; the starch-grains, instead of being round or oval, and with a central hilum and obscure rings, are pyriform, with an eccentric hilum placed at the smaller end, and with well-marked concentric rings. Weak liquor potassæ (1 drop of liq. pot. B.P. to 10 of water) swells them out greatly after a time, while wheat-starch is little affected by this strength ; if the strength is 1 to 3 (as in the figure), the swelling is very rapid.

Detection of Maize (*Indian Corn*).—There are two envelopes ; the outer being made up of seven or eight strata of cells ; there is no transverse second coat, as in wheat ; the internal coat consists of a single stratum of cells like the fourth of wheat, but less regular in shape and size. The cellulose, through the seed holding the starch in its meshes, forms a very characteristic structure, which on section looks like a pavement made of triangular, square or polygonal pieces ; the cells are filled with the starch-

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the puncheons which hold them. The larvæ are soon hatched, and by means of strong jaws and active legs scrape and bore their way through crevices ; they eat the biscuit, and spoil more than they eat by spinning their webs over the biscuit. Cocoa stores swarm with the moths and larvæ, and they even penetrated into many parts of H.M.S. Hercules.

After examining into the ravages caused by these larvæ in the biscuit at Gibraltar, Mr. Huxley made the following suggestions:

1. To have no cocoa stored in any place in which biscuits are manufactured.
2. To head up all biscuit puncheons as soon as they are full of the freshly baked biscuit.
3. Coat puncheons with tar after they are headed up, or at least work lime-wash well into all the joints and crevices.
4. Line the bread-rooms of ships with tin, so that if the *Ephestia* has got into a puncheon it may not get into the rest of the ship.
5. If other means fail, expose woodwork of puncheons to a heat of 200° Fahr. for two hours.

grains, which are very small, and compressed, so as to have facets. They are very different from the smooth, uncompressed round cells of wheat.

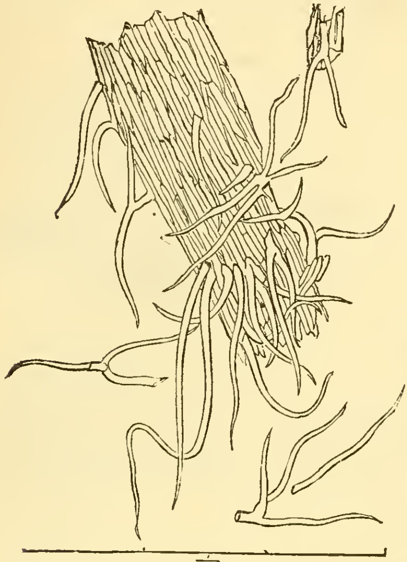


FIG. 36.—Outer Coat and Hairs of Barley (low power).

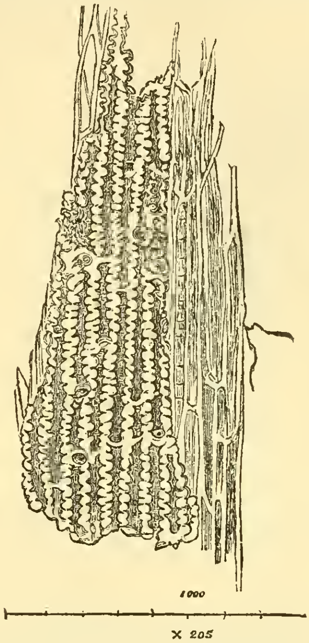


FIG. 37.—Outer Coat of Barley (higher power).

Bits of cellulose, with its peculiar angular markings, are always found if the wheat is adulterated with maize.

Detection of Bean and Pea.—These adulterations are also at once dis-

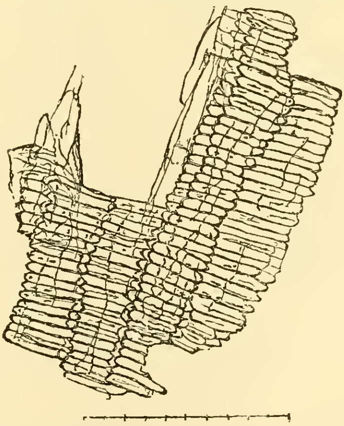


FIG 38.—Barley (second and third coats).

covered; the meshes of cellulose are very much larger than those of the fourth coat of wheat, with which it has sometimes been confounded, and

the starch-grains are also quite different; they are oval or reniform, or with one end slightly larger; they have no clear hilum or rings, but many have a deep central longitudinal cleft running in the longer axis, and occupying two-thirds or three-fourths of the length, but never reaching

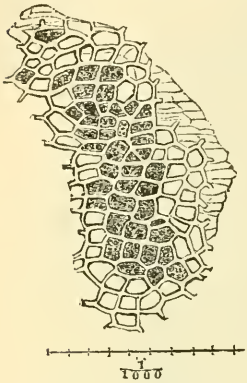


FIG. 39.—Barley (fourth coat)

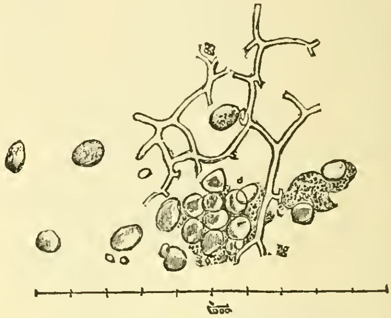


FIG. 40.—Barley (Starch-grains).

completely to the end; this cleft is sometimes a line, sometimes almost a chasm, and occasionally secondary clefts abut upon it at parts of its course; sometimes, instead of a cleft, there is an irregular-shaped depression. If a little liquor potassæ be added, the cellulose is seen more clearly. Pea-

FIG. 41.—Potato Starch × 285. See also Plate of Starches.

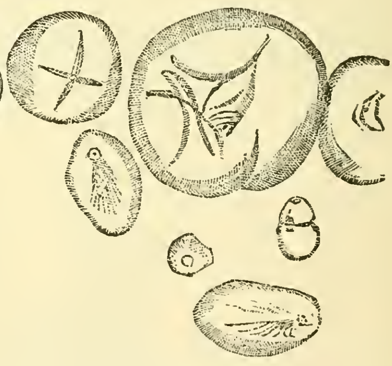


FIG. 42.—Medium and small-sized Potato Starch-grains, treated with Liq. Pot. B.P. (strength 1 to 3), and × 285.

flour is never added to a greater extent than 4 per cent., as it makes the bread heavy and dark. If the flour be mixed with a little boiling water, the smell of the pea or bean is perceptible.

Detection of Oat.—There are two or three envelopes; the outer longitudinal cells; the second obliquely transverse, and not very clearly seen; the cells are wanting in parts, or pass into the cells of the third coat; the third a layer, usually single, of cells like wheat. The husk must be detached before the envelopes are looked for. The starch-cells are small, many-

sided, and cohere into composite round bodies, which are very characteristic, and which can be broken down into the separate grains by pressure. A high power is the best for this. The oat starch does not polarize light. There is no difficulty in the detection of the starch-grains.

Detection of Rice.—The husk of rice is very peculiar ; on the outer coat are numerous siliceous granules, arranged in longitudinal and transverse

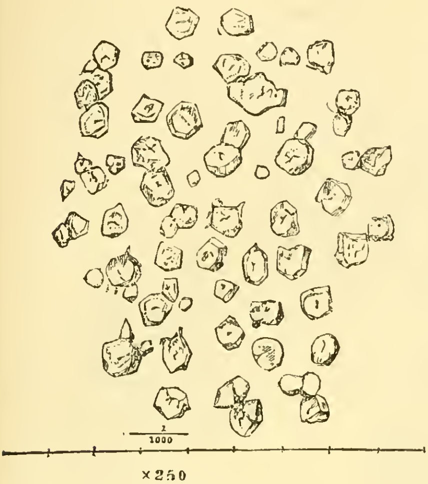
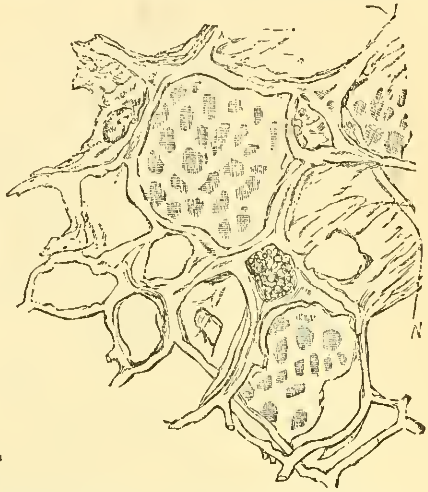


FIG. 43.—Indian-Corn Flour. See also Plate of Starches.



Cellulose of Indian Corn, × 500, with markings from the Starch-grains on the intercellular membrane.

ridges (Figs. 49 and 50) (*a*). There are numerous hairs, some of which are seated over stomata. Below this is a membrane of transverse and longitudinal rough-edged fibres (*b c*), while below these again is a fine

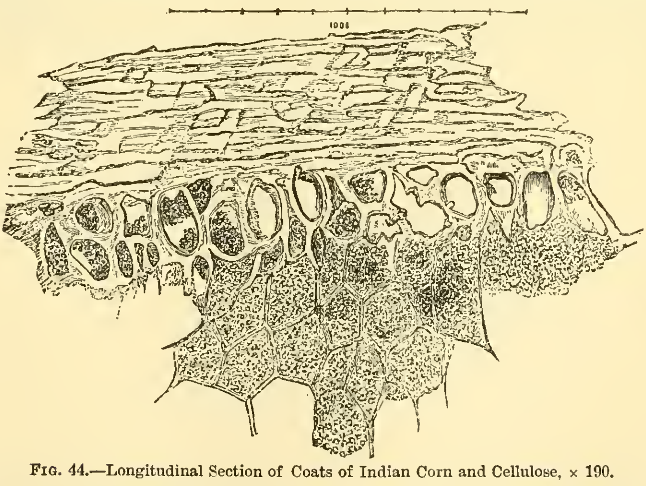


FIG. 44.—Longitudinal Section of Coats of Indian Corn and Cellulose, × 190.

membrane of transverse angular cells (*d*), covering a very delicate membrane of large cells. The starch corpuscles are very small (Fig. 48) ; angular under low powers ; under high powers they are seen to be facetted

and compressed. They cannot be mistaken for the round cells of wheat, but may be confounded with oat starch, from which, however, they are distinguished by the absence of the compound cells or glomeruli. Their shape is also a little like maize, but they are very much smaller.

Detection of Rye.—The envelopes are very like those of wheat, and can

Fig. 45.—Bean Starch.

perhaps hardly be distinguished from them. The recent starch-grains are also like those of wheat, but they are much more distinctly spherical. They have also sometimes a peculiar rayed hilum, which used to be thought

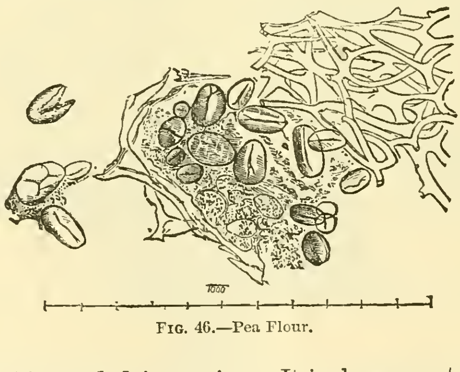


Fig. 46.—Pea Flour.

peculiar to the older and drier grains. It is, however, to be seen even in the starch of fresh soft grains, whilst the plant is still green. In the starch of wheat it is only met with occasionally, when the grain is very old or dry.

Rye, if in any quantity, is discovered by baking; it makes a dark, acid bread.

Linseed is not a common adulterant. The envelopes are peculiar: the external is made up of hexagonal cells, containing oil; the second of round

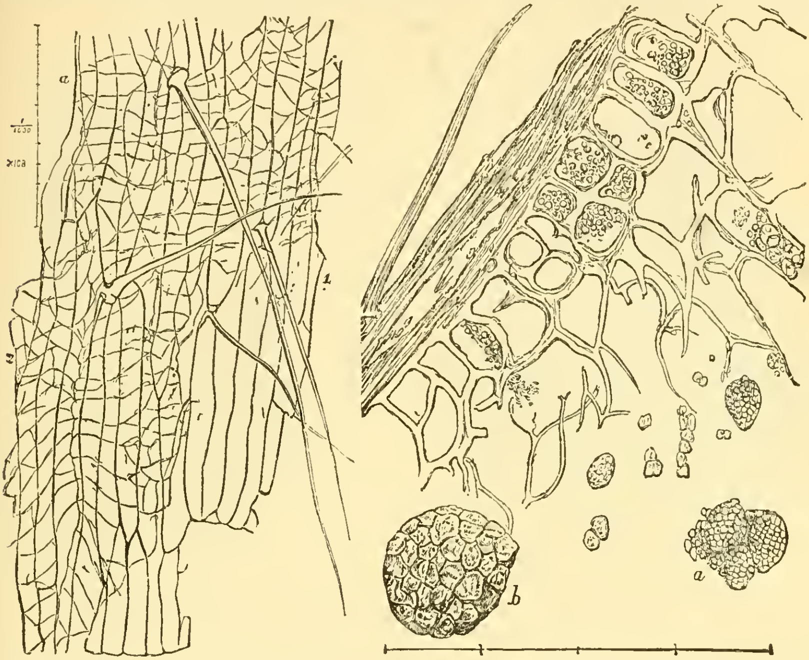


FIG. 47.—White Oat (long. sect., 2d and 3d coats not separable). *a* Compound grains, × 100. *b* One do., × 500.

cells; the third of fibres; and the fourth of angular cells, containing a dark reddish coloring matter.

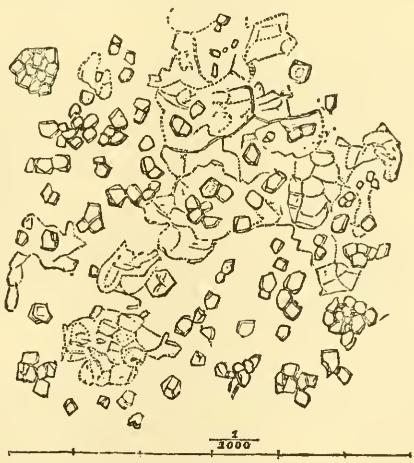


FIG. 48.—Ground Rice Flour, × 350.

Buckwheat (*Polygonum Fagopyrum*, or *Fagopyrum esculentum*).—Like rye, this is only likely to be found in wheat coming from the Baltic. The

drawing sufficiently shows the texture of the envelopes, which is very complicated. The starch-grains are small and round, and adhere together in masses. Under a high power there are indications of concentric rings. Bread made with this grain has a darkish, somewhat violet, color.

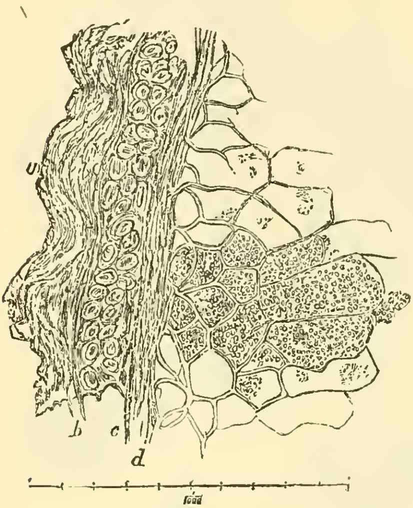


Fig. 49.—Rice, × 170.

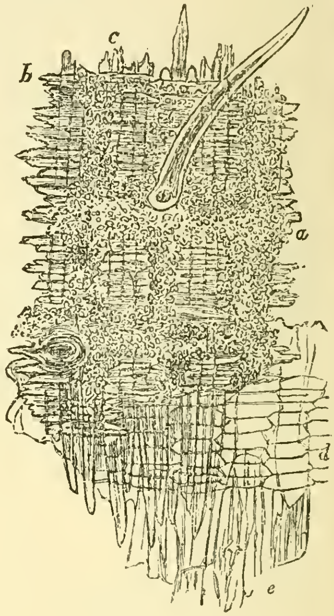


Fig. 50.—Rice, × 178.

Fig. 49. Transverse Section of the Husk of Rice .... } × 170.
Fig. 50. Appearance of Husk of Rice as seen in a transparent medium of glycerine and gum. }
a, Siliceous granules, arranged in longitudinal and transverse ridges, perforated by openings—stomata, some having hairs seated over them. *b c*, Transverse and longitudinal, brittle, rough-edged fibres. *d*, A fine membrane of transverse angular cells; these overlie a very delicate membrane of large cells, *e*.

Millet.—In India, Egypt, China, and West Coast of Africa, millet of some kind is likely to be an adulteration. Dr. Maddox's drawing (page 259) shows the beautiful structure of the envelopes, which could not be confounded with those of wheat. The starch-grains are very small, round, and tolerably uniform in size.

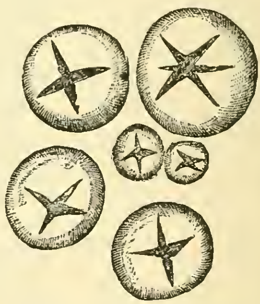


Fig. 51.—Rye-starch, with rayed hilum (after Hassall), × 420.

Melampyrum arvense and other species (Purple cow-wheat—*Scrophulariaceæ*).—This has occasionally been mixed with flour; it is not injurious, but gives the bread (not the flour) a peculiar smoky violet or bluish-violet tint. This depends on a coloring matter in the seed, which, when warmed with acid, gives the violet color.[1]

Trifolium arvense (Trefoil—*Leguminosæ*).—This also gives the bread a red-violet color. It is not known to be injurious.

Rhinanthus major and *crista galli* (Yellow-rattle—*Scrophulariaceæ*) gives bread a bluish-black color, a moist, sticky feel, and a disagreeable sweet

[1] Pellischek, Schmidt's Jahrb., 1863, No. 3, p. 287.

taste. It is not injurious. *Onobrychis sativa* (Sainfoin—*Leguminosæ*) has also been used.

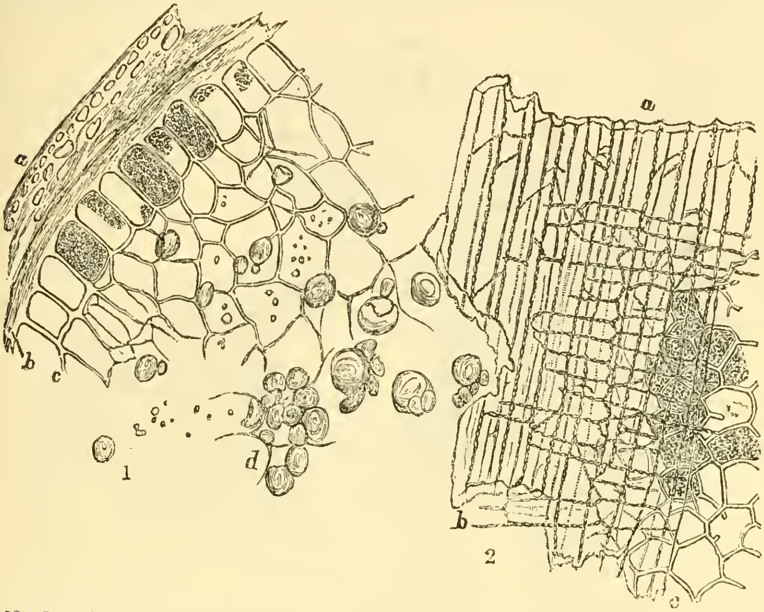


FIG. 52.—Rye—1. Transverse Section of Testa, etc., × 108; 2. Coats *in situ* from without, × 170. *a*, External; *b*, Middle; *c*, Internal coat; *d*, Starch-grains × 108.

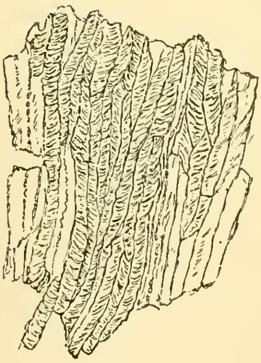
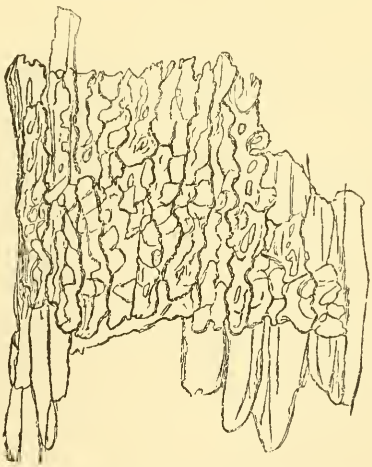


FIG. 53.—Outer coat of Buckwheat, apparently of irregular and interlacing fibrospiral cells, separable by boiling the testa and macerating it. Outside these cells is a very thin and delicate membrane, retaining the marks of attachment of the spiral cells, × 170.



Internal coats. The most internal is composed of cells with an irregular waved outline, and longitudinal cells over the starch-cells, × 170.

Lolium temulentum (Darnel—*Gramineæ;* other species may be used).

—This gives the bread no color, but produces narcotic symptoms, vertigo, hallucinations, delirium, convulsions, and paralysis.[1] Pellischek states that these symptoms do not occur if the grain be dried in an oven before

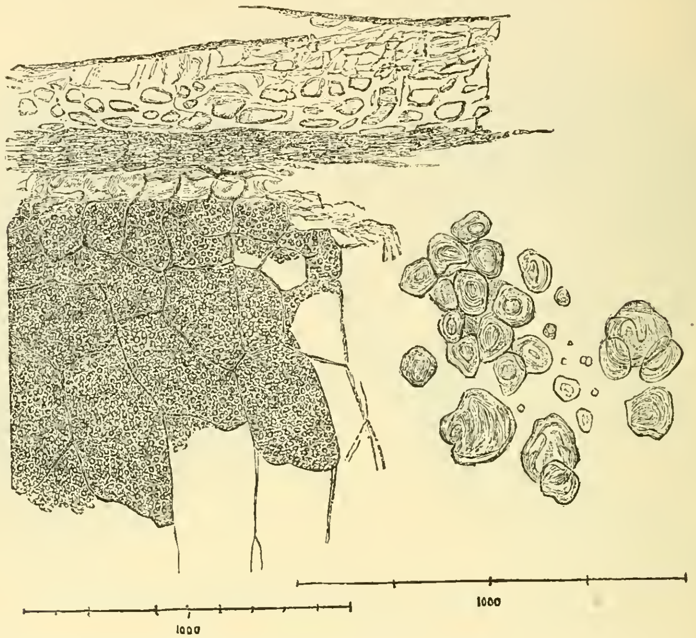


FIG. 54.—Buckwheat—transverse section of outer, middle, and internal coats, with cellulose containing starch-grains .... } ×170. Starch-grains ×500.

baking, or if the bread is left for some days before being used. The detection of the lolium is best effected by means of alcohol, which gives a greenish solution with a disagreeable, repulsive taste, and on evaporation

[1] The peculiar symptoms produced by *Lolium temulentum*, or bearded Darnel, were well known to the ancients. Pereira states that the first symptoms are gastro-intestinal, such as vomiting and colic, and then cerebro-spinal symptoms come on, viz., headache, giddiness, tinnitus, confusion of sight, dilated pupils, delirium, trembling and paralysis (Elements of Materia Medica, 1850, vol. ii., p. 977). The same effects are produced on animals. Pereira states that he did not succed in obtaining the chemical test noted in the text, viz., the green alcoholic solution and the yellow resin on evaporation. Hassall figures the starch-grains of the lolium as small and something like rice; fifty or sixty may adhere together and form a compound grain not very unlike the oat. The envelopes are tolerably distinctive; the cells of the outer coat are made up of a single layer, and are disposed transversely instead of longitudinally. The second coat is in two layers, and the cells have a vertical arrangement. The third coat is like the inner coat of wheat. This account is taken from Hassall.

It is not very likely that any other grains except those mentioned in the text will be mixed with wheat flour. The seeds of the Peruvian food, the *Chenopodium Quinoa* have not apparently been used as a falsification. The starch-grain of the Quinoa are said to be the smallest known. It may be worth remarking that this seed is very rich in salts (2.4 per cent.), and particularly so in iron (.75 per cent.); indeed, it is the richest in iron of any vegetable. It is possible that it might be a useful food in some cases of illness. It is fairly nutritious and digestible.

The starch-grains of the acorn, which might perhaps be added in times of great scarcity, would be immediately detected, as they have a very characteristic central depression, and are also quite different in shape from the flat, round, smooth starch-cells of the wheat and barley.

a resinous yellow-green disagreeable extract is left. Pure flour gives with alcohol only a clean straw-colored solution, with an agreeable taste (Pellischek).

Bromus or *Serrafalcus* (Brome-grass—*Gramineæ;* different species—*Arvensis* or *Secalinus*).—Pellischek states that the seeds of this plant give the bread a dark color, and make it indigestible. It is probably a most uncommon adulteration.

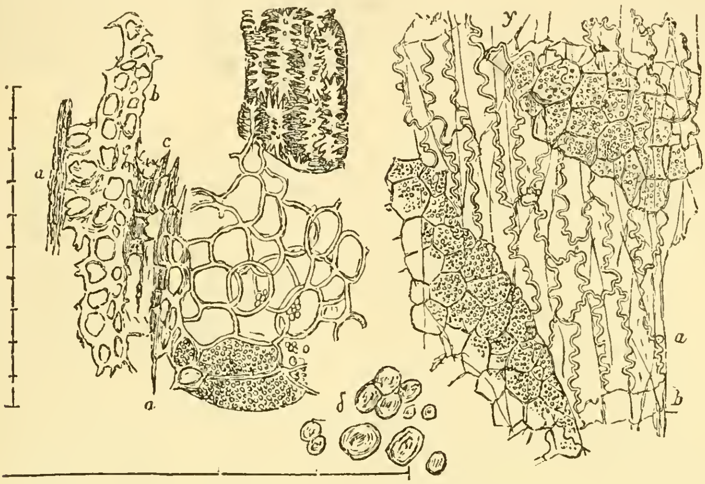


FIG. 55.—Millet Seed—*a*, Transverse Section of Testa Coats, seen from inside. *a*, Outer; *b*, Middle; *c*, Inner coat × 170; δ, Starch-grains × 500. Scale 1-1000th inch.

It will be found that, when mixed with flour, the microscope will detect readily many of these substances. Detection is often very difficult when the flour is made into bread, and therefore, whenever from the bread there is any cause of suspicion, means should be taken to obtain some of the flour.

Cones Flour.—A flour obtained from Revel wheat is used by bakers for dusting their troughs. Hassall has found this Cones flour to be greatly adulterated with rice,[1] maize, beans, rye, and barley. Sometimes Cones flour is mixed with good flour.

Cooking of Flour.

The effect of heat is to coagulate the albumen, and to transform some of the starch into dextrin. Substances are also added to the bread to cause a further transformation of the starch.

Cakes.—The unfermented cakes[2] are simply made with water and salt. As they are very readily made, are agreeable to taste, and nutritious, it is very desirable to teach every soldier to make them; so that in war, when bread is not procurable, he may not be confined altogether to biscuit. The Australian "damper" is simply made by digging a hole in the ground, filling it with a wood fire, and, when the fire has thoroughly burnt up, re-

[1] Several samples I have examined contained nothing but rice. This is sometimes sold as "Rice Cones."—(F de C.)

[2] The Chupatty of India.

moving it, placing the dough on a large stone, covering it with a tin plate, and heaping the hot ashes round and over it. In a campaign, every soldier, if he could get flour and wood, would soon learn to bake a cake for himself. The only point of manipulation which requires practice is not to have the heat too great ; if it be above 212° too much of the starch is changed into dextrin, and the cake is tough. Exposed to greater heat, and well dried, the unfermented cakes become biscuit.

Macaroni is flour from a hard Italian grain, moistened with water, and pressed through a number of small openings, while at the same time heat is applied. As it is very nutritious in small bulk, and keeps well, it would be a good food for soldiers in war if its cost could be lessened.

Sub-Section III.—Biscuit.

To make biscuit, flour is often taken with little or no bran (on account of the hygroscopic properties of bran) ; but bran is also sometimes used ; no salt is added. The simplest biscuits are merely flour and water. Some biscuits are made with milk, eggs, etc.

Choice of Biscuit.—Biscuit should be well baked, but not burnt ; of a light yellow color, and should float and partially dissolve in water ; when struck, it should give a ringing sound ; and a piece put into the mouth should thoroughly soften down. It should be free from weevils, which are easily seen.

Advantages as a Diet.—As it contains little water, and, bulk for bulk, is more nutritious than bread, three-fourths of a pound are usually taken to equal 1 ℔ of bread. Its bulk is small, and it is easily transported.

Disadvantages.—Like flour, it is deficient in fat. After a time, it seems difficult of digestion. Perhaps the want of variety is objectionable ; but certain it is, that men do not thrive well upon it for long periods. In war, it has always been a rule with the best English army surgeons, for more than a century, to issue bread as much as possible, and to use biscuit only in cases where it cannot be avoided.

Sub-Section IV.—Bread.

If carbon dioxide gas is any way formed in or forced into the interior of dough, so as to divide the dough into a number of little cavities, bread is made.

There are three kinds of bread :

1. Carbon dioxide is disengaged by a fermentative process, caused by yeast or leaven. During the baking a certain amount of performed sugar yields CO_2 ; a portion of starch is converted into dextrin and sugar, and also yields CO_2 ; a little lactic and butyric acids, and extractive matters are formed. It is of importance to prevent this change from going too far ; and herein is one of the arts of the baker ; and it is partly to prevent this that alum is added, which has the property of arresting the change.

In making bread, the proportions are 20 ℔ of flour ; 8 to 12 ℔ of tepid water ; 4 oz. of yeast, to which a little potato is added, and 1½ to 2 oz. of salt ; 280 ℔ of flour (1 sack) will give from 90 to 105 4-℔ loaves ; or 100 ℔ of flour will make from 129 to 150 ℔ of bread. If there is 14 per cent. of water in the flour, the bread will contain in the former case 33.1 per cent., and in the latter, 42.7 per cent. If 100 ℔ of flour contain 14 per cent. of water, and make 141½ ℔ of bread, the bread will contain 40 per cent. of water ; the baker always endeavors to combine as much water as he can

so as to get more loaves. 6½ ℔ of dough yield 6 ℔ of bread. Machines are now generally used for mixing the dough (Stevens' Machine).

2. CO_2 is disengaged by mixing sodium or ammonium carbonate with the dough, and adding hydrochloric, tartaric, phosphoric, or citric acids. Baking powders are compounds of these substances.

3. CO_2 is forced through the dough by pressure (Dauglish's patent aërated bread). This process has the great advantage of rendering it impossible that the conversion of starch into dextrin, sugar, and lactic acid shall go too far. About 20 cubic feet of CO_2 (derived from chalk and sulphuric acid) are used, for 280 ℔ of flour; and about 11 cubic feet are actually incorporated with the flour (Odling).

Advantages of Bread as an Article of Diet.

It is hardly necessary to mention these. The great amount of nitrogenous matters and starch it shares with flour; the nitrogen is to the carbon as 1 to 21. It therefore requires more nitrogen for a perfect food. The process of baking renders it more digestible than flour. No satiety attends its use, although it may be always made in the same way; this is probably owing to the great variety of its components.

Disadvantages.—It is poor in fat and some salts, especially in the case of the finest flour freed from the internal envelope. Therefore we see that the practice of using fat with it (butter for the rich, fat bacon for the poor man) is extremely common. As to the relative advantages of the three methods of making bread, the last (aëration by CO_2) is said to have the advantage of making white bread, though the inner envelopes are left; of not causing any loss of starch, or permitting the change to go too far; of not containing any unwholesome yeast. The systen of making bread with yeast has been objected to on the ground that bad yeast is often used; the fermentative changes go on in the stomach, much CO_2 is disengaged, and dyspepsia, flatulence, and unpleasant sensations, such as heart-burn, are produced. There is no doubt that badly prepared bread gives rise to these symptoms, though that this is owing to bad yeast is at least uncertain. The second method yields a wholesome bread, but is too expensive for common use, and it has also been pointed out that the hydrochloric acid of commerce always contains arsenic. The amount would be too small to be hurtful, but might be of medico-legal consequence.

Special Points about Making of Bread.

Bread may be of bad color—rather yellowish, from old flour; from grown flour (in which case the changes in the starch have generally gone on to a considerable extent, and the bread contains more sugar than usual, and does not rise well), and perhaps from bad yeast. The color given by admixture of bran must not be confounded with yellowness of this kind.

Bread is also dark colored from admixture of other grains, as already noticed under flour (rye, buckwheat, melampyrum, sainfoin, etc.). Bread may be acid, from bad flour giving rise to an excess of lactic and perhaps acetic acids, or, it is said, from bad yeast. In finding the cause of acidity in bread, look first to the flour, which may be old, and a little discolored, and too acid; if nothing can be made out, examine the yeast, and change the source of supply; then look to the vessels in which the dough is kneaded, and to the water. Enforce great cleanliness on the part of the men who make up the dough. In India bread becomes sour from bad

cleaning of the flour. Dr. Godwin, A.M.D.,[1] states that at Bareilly the wheat was imperfectly ground in small hand-mills; it was then separated by shifting into four portions, viz., bran; "attar," which corresponds to pollards; "soojie," which consists of gluten and starch; and "maida," which is nearly all starch. The soojie, from imperfect grinding, is granulated, and chiefly used for bread, a small portion only of maida being mixed with it. To cleanse the wheat before grinding it, it was washed and then dried in heaps in the sun; this caused fermentation and a rapid development of acidity. The heaps of corn were quite hot to the feel. A very acid bread was given, but when the wheat was not thus washed it yielded a good bread.

Bread is heavy and sodden from bad yeast fermenting too rapidly, or when the fermentation has not taken place (cold weather, bad water, or some other cause, will sometimes hinder it), or when the wheat is grown; when too little or too much heat has been employed. It is said also, that if the flour has been dried at too great a heat (above 200° Fahr.), the gluten is altered, and the bread does not rise well. It is bitter from bitter yeast.

It becomes mouldy rapidly when it contains an excess of water.

Rice is used as an addition because it is cheaper; it retains water, and therefore the bread is heavier. Rice bread (if 25 per cent. of rice be added) is heavier, of closer texture, and less filled with cavities. Potatoes are sometimes added, but are generally used only in small quantity with the yeast.

Alum is added to stop an excess of fermentation, when the altering gluten or cerealin acts too much on the starch, and it also whitens the bread; it does not increase the amount of water; it enables bread to be made from flour which otherwise could not be used. Sulphates of copper and of zinc, in very small amount, are sometimes employed for the same purpose.

For acid flour, lime-water is used instead of pure water; lime-water has this advantage that, while it does not check the fermentation of yeast, it hinders the action of diastase on starch. It must be caustic lime-water, and not chalk and water, as sometimes is the case.

Loaves are generally weighed when hot, and that is considered to be their weight. In the Austrian army, a loss of 2.9 per cent. in four days is permitted.

After being taken from the oven bread begins to lose weight.[2]

The loss of weight depends upon size, amount of crust, temperature, and movement of air.

In a sheltered place, at ordinary temperature, a 2-℔ loaf, baked with crust all over, loses about $\frac{3}{4}$ per cent. in cooling, and from 1 to $1\frac{1}{4}$ in five hours.

A similar loaf, with only top and bottom crust, loses 3 per cent. in cooling, and about 4 per cent. in five or six hours. A loaf with four sides crust loses 2 per cent. in cooling, and retains its weight without much further loss for five hours. For each of six sides that is not crust there is a loss of weight of about 1 per cent. in the first five hours.

At the end of twenty-four hours the proportion is about one-half more, and the total loss is doubled at the end of seventy-two hours (three days). If the bread is baked in larger loaves (4 ℔, for instance) the loss will be

[1] Army Medical Report, vol. vii., p. 451.
[2] See Report on Hygiene, Army Medical Reports, vol. xviii., p. 219.

proportionately less, the ratio of the evaporating surface to the bulk of the loaf being diminished.

When loaves become stale they can be dipped in water and rebaked, and then taste quite fresh for twenty-four hours; after that they rapidly change.

Old biscuit also, soaked in water, can be rebaked, and becomes palatable.

In the French army different kinds of bread are used:[1] ordinary bread; biscuited bread; bread half biscuited; bread one quarter biscuited; hospital bread. The "Pain biscuité" is used only on service; it is baked more firmly than ordinary bread.

Pain de munition ordinaire keeps 5 days in summer and 8 in winter.
" au quart biscuité " 10 to 15 days.
" demi " " 20 to 30 "
" biscuité " 40 to 50 "

The French munition loaf weighs 1.5 kilogrammes (3.3 ℔ avoir.), and contains two rations of 760 grammes (each 1.65 ℔). The ration of biscuit is 550 grammes (1.2 ℔).

It would be useful to adopt the practice of strongly baked bread in our army; it is a good substitute for biscuit.

Examination of Bread.

There is, perhaps, no article on which the medical officer is more often called to give an opinion.

General Characters.—There should be a due proportion, not less than 30 per cent., of crust; the external surface should be well baked, not burnt; the crumb should be permeated with small regular cavities; no parts should be heavy, and without these little cells; the partitions between the cavities should not be tough; the color should be white or brownish from admixture of bran; the taste not acid, even when held in the mouth. If the bread is acid the flour is bad, or leaven has been used; if the color changes soon, and *fungi* form, the bread is too moist; if sodden and heavy, the flour is bad, or the baking is in fault; the heat may have been too great, or the sponge badly set.

Chemical Examination.—This is conducted chiefly to ascertain the amount of water and acidity, and the presence of alum or sulphate of copper.

Water.—Take a weighed quantity (say 10 grammes) of crumb, and dry in a water bath; powder, and then dry again in a hot-air bath or oven, and weigh; the water should not be more than 45 per cent.; if more, the bread is *pro tanto* less nutritious, and is liable to become sooner mouldy.

Acidity.—This can be determined by a standard alkaline solution.[2]

In two samples of fresh good bread examined at Netley, the percentages of acidity (reckoned as glacial acetic) were respectively 0.054 and 0.055 (3.78 and 3.85 grains per ℔); in a sample rather underbaked, but fairly good, 0.072 per cent. (5.04 grains per ℔); and in three samples, condemned as inferior, 0.085, 0.088, and 0.104 per cent. respectively (5.95, 6.16, and 7.28 grains per ℔).[3] On another occasion, two samples of fairly good bread yielded 0.102 and 0.12 per cent. (7.14 and 8.4 per ℔ respectively); and

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[1] Code des Officiers de Santé, 1863.
[2] See Appendix A, Vol. II.
[3] Report on Hygiene, Army Medical Reports, vol. xviii., p. 222.

two others, from bakers in the neighborhood, 0.084 and 0.090 (5.88 and 6.30 per ℔ respectively). A sample condemned as sour yielded 0.18 (12.6 per ℔); 8 grains per ℔ (0.114 per cent.) ought certainly to be the limit.

Alum.—The determination of the presence of alum is not difficult, but the quantitative analysis is necessary, since it has been shown by Wanklyn that unalumed bread may contain an appreciable amount. Many processes have been proposed,[1] some of which are merely modifications of each other. The process described in the foot note seems the most simple.[2]

Wanklyn considers that unalumed bread may contain 5 or 6 milligrammes of phosphate of aluminium in every 100 grammes of bread (= 0.005 per cent.). This is equal to about 1½ grain of crystallized alum per ℔ of bread. It will be well to deduct this amount from the total amount of phosphate of aluminium found; the remainder will represent the amount

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[1] By Kuhlmann, Letheby, Odling, Wentworth Scott, Crookes, Hassall, Hadow, Horsley, Dupré, Wanklyn.

[2] *1st part.*—Take at least ½ ℔ of crumb, put it in a mortar, and soak it well in cold distilled water; filter, and get as clear a fluid as possible; add a few drops of hydrochloric acid, and then chloride of barium If there is no precipitate no alum can have been added, and the process need not be proceeded with. If there is a slight precipitate, it may be accounted for by sulphate of lime or magnesia in the water used in baking, or of sulphate of magnesia in the salt, or by the slight amount of sulphuric acid naturally existing in the grain, or added during the grinding. Perhaps the medical officer will know whether the water or the salt contains sulphates, and if so, the absence of alum may be inferred. If there be a large precipitate, the presence of alum is probable, but is not certain, and the process must be continued.

2d part.—Dupré's process, as modified by Wanklyn, seems on the whole the simplest and least liable to error, as it gets rid of one great source of fallacy, namely, the presence of alumina in the liquor potassæ, which reagent is not required. The process is as follows: Take 100 grammes (= 3½ ounces) of bread; incinerate for four or five hours in a platinum dish to a gray ash; weigh (the ash should not sensibly exceed 2 grammes); moisten with 3 C.C. of pure hydrochloric acid to separate silica; add 20 to 30 C.C. of distilled water, boil, filter, wash the filter well with boiling water; add to the filtrate, which contains the phosphates of calcium, magnesium, aluminium, and iron, 5 C.C. of liquor ammoniæ (sp. gr. 880), which causes a precipitate of these phosphates; then add gradually 20 C.C. of strong acetic acid, which partially clears the fluid by dissolving the phosphates of calcium and magnesium; boil and filter. The undissolved part is a mixture of phosphate of aluminium and phosphate of iron; wash, precipitate well with boiling water, dry, ignite, and weigh.

The iron must now be determined in this precipitate. This may be done by the permanganate, but Wanklyn's colorimetric test is probably better: it is as follows: Dissolve 1 gramme of pure iron wire in nitro-hydrochloric acid, precipitate the ferric oxide with ammonia; wash the precipitate, dissolve it in a little hydrochloric acid, and dilute to 1 litre: one C.C. therefore equals 1 milligramme of metallic iron; when used it is diluted 1 in 100 so as to make a solution, of which each C.C. contains $\frac{1}{100}$th milligramme (= 0.01 of a milligramme) of metallic iron. To use this, dissolve the phosphates of aluminium and iron (obtained by the above described process) in pure hydrochloric acid, and dilute to 100 C.C. Test the solution to see if it give a deep color with ferrocyanide of potassium; if the color is not too deep take 50 C.C. of the solution, but if it be deep take a smaller quantity, and make it up to 50 C.C. with distilled water, taking care that it is well acidulated. Put it into a cylindrical glass, and add 1 or 2 C.C. of solution of ferrocyande of potassium: a blue color is given. Into another glass 1 C.C. of strong hydrochloric acid is put, and 50 C.C. of distilled water; 1 or 2 C.C. of ferrocyanide are added; the standard solution of iron is then dropped in till an equal color is produced. The amount of iron is then read off and calculated as phosphate (1 of iron = 2.696 $FePO_4$). Deduct the weight from the total weight of phosphate of aluminium and iron; the remainder is phosphate of aluminium (= $AlPO_4$), of which 1 part equals 0.42 alumina, or 2.1 dry or 3.9 crystallized potassium alum; or 1.9 dry or 3.7 of crystallized ammonium alum, which last is almost the only kind now in the market.

Winter-Blyth (Analyst, vol. vii., 1882, p. 19) proposes to dissolve out the added alumina by long digesting in a large bulk of 5 per cent. hydrochloric acid Should this succeed it will simplify the operation.

corresponding to alum added. Carter Bell[1] deducts 10 grains per 4-lb loaf, or 2½ grains per lb, before reckoning adulteration.

Dr. Letheby also used a decoction of logwood as a test; a piece of pure bread and a piece of suspected bread are put into a glass containing freshly prepared decoction, and left for twenty-four hours; the pure bread is simply stained, the alumed bread is dark purplish, as the alum acts like a mordant. Mr. Hadow and Mr. Horsley[2] have also used this test with advantage, but Mr. Crooks, after many experiments, came to the conclusion that it was valueless.[3] Winter-Blyth proposes the use of slips of gelatine soaked in the aqueous solution of the suspected bread. If the bread is pure the gelatine is stained only a reddish-brown by logwood, and can be decolorized by glycerine; alumed bread gives a more or less deep blue color, which is permanent in glycerine.

Alum is not much used except with inferior bread.[4] The amount of alum in bread is said to be, on an average, 3 ounces to a sack or 280 lb of flour; if the sack gives 105 4-lb loaves, there will be 3 grains in a lb of bread; but if crystallized alum is meant by this, there will only be about 1½ grain of dry alum. Hassall states the quantity to be ½ lb (8 ounces) to 240 lb of flour, but that the quantity differs for old and new flour. A very good witness,[5] in the inquiry into the grievances of the journeymen bakers, gave the quantity at 10 ounces per sack; this would give 41.6 grains per 4-lb loaf, or 10.4 grains per lb. When mixed with flour and baked, the alum is decomposed, part of the alumina combines most strongly with phosphoric acid; and either this or the alum itself is presumed to be in combination with the gluten; potassium disulphate is probably formed.

Cupric Sulphate.—Cut a smooth slice of bread, and draw over it a glass rod dipped in potassium ferrocyanide. If copper be present, a brick-red color is given by the formation of ferrocyanide of copper. The test is very delicate. It is believed to be a very rare adulteration in England. It has been said that cobalt is used instead of copper, but it is also probably very rare; it can be detected by the blueness of the ash.[6]

Potatoes.—If potatoes in any quantity have been added, the ash of the bread, instead of being neutral, is alkaline; this can only occur from sodium carbonate having been added, or from the presence of some salts of organic acids, citrates, lactates, tartrates, which form carbonates on incineration. But if it be from sodium carbonate, the solution of bread will be alkaline, so that it can be known if the alkalinity is produced during incineration. If so, it is almost certain to be from potato.

Examination of Yeast.—Common brewers' yeast is not likely to be adulterated. If any solid mineral substances are mixed with German yeast, they are detected either by washing or by incineration. Dr. Letheby found German yeast, imported in 1863, to be adulterated with 30 per cent. of pipe-clay.

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[1] Analyst, No. 40, 1879, p. 126.

[2] Chemical News, May, 1872.

[3] Ibid., September, 1862.

[4] Report on Journeymen Bakers, 1862, p. 164; see also Odling's Papers. Hassall, however, found alum in half the loaves examined. A writer in the Lancet (January, 1872) states that at that date alum was found in 10 out of 20 loaves, and the amount was from 12 to 96 grains in the 4-lb loaf.

[5] Report on Journeymen Bakers, 1862, p. 163. Some of the statements are beyond even this amount—1 lb to 4 lb per 1,000 (4-lb ?) loaves (p. xxxvi.); but this is probably an exaggeration.

[6] Dr. Campbell Brown.

Microscopical Examination of Bread.

This is of very little use as far as adulteration is concerned, but the presence of *fungi* can be detected.

The most common *fungus* is a kind of *Penicillium* (*sitophilum* and *roseum*), which gives a greenish, brownish, or reddish-yellow color ; sporules, sporangia, and mycelium can all be seen. The *Oidium aurantiacum* has been several times detected in France and Algeria ; it is distinguished by its orange-red color. A greenish *mucor* is often found in bread. *Puccinia*, so common in flour, has not been detected.

Diseases connected with the Quality of Flour and Bread.

1. *The Flour originally bad.*—It may be ergoted, or grown and fermenting, or with *fungi* forming. An anomalous disease approaching to ergotism should lead at once to an examination of the flour. The fermenting flour produces dyspepsia and diarrhœa ; the heat and moisture of the stomach, no doubt, excite at once very rapid fermentation ; the gluten, already metamorphosing, acts very energetically on the starch, and CO_2 is rapidly developed ; hence uncomfortable feelings, flatulence, imperfect digestion, and diarrhœa. It is to remedy this condition of flour that alum is added, and some of the effects ascribed to alum may be really owing to the flour.

The most important disease connected with flour is, however, ergotism ; this is less common in wheat than in rye flour, but yet is occasionally seen. Sometimes ergoted meal produces at once violent stomach and intestinal symptoms, at other times primary digestion is well performed, and the early symptoms are great general depression and feverishness, ushering in the local symptoms of acrodynia.

2. *Flour originally good, but altering either from age or from not having been well dried.*—The bread is often acid, and sometimes highly so ; this may produce diarrhœa, though such bread has sometimes been used for a long time without this effect ; usually persons will not eat much of it, and thus the supply of nutriment is lessened. If the bread be too moist, *fungi* form, and *Oidium aurantiacum*, in particular, has been known in Algiers to give rise to little endemics of diarrhœa (Boudin and Foster).[1] *Mucor mucedo* either does not produce this, or rarely. It should be remembered, however, that mouldy oats (the *fungus* being *Aspergillus*) have given rise to paralytic symptoms in horses, so that these *fungi* are to be looked on with suspicion ;[2] and a case of the kind has been reported by H. Hoffman in Giessen.[3] Professor Varnell also states[4] that six horses died in three days from eating mouldy oats ; there was a large amount of matted mycelium, and this, when given to other horses for experiment, killed them in thirty-six hours ; there was a "peculiar growth" on the mucous membrane of the small intestine. It is not known that *Acarus*, so common in flour, has any bad effects when eaten.

3. *Substances added.*—*Alum*, of course, is the chief substance ; there has been much difference of opinion as to its effects. It has been asserted to produce dyspepsia ; to lessen the nutritive value of bread by rendering the phosphoric acid insoluble, and to be also a falsification, inasmuch as it

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[1] Archives Gen. de Méd., 1848, p. 244.
[2] Sanderson's Report in Syd. Soc. Year-Book for 1862, p. 462.
[3] Virchow's Archiv, Band xliii., p. 173.
[4] Journal of the Society of Arts, April, 1865.

permits an inferior flour to be sold for a good one. The last allegation is no doubt correct; the second probably so, as there is little doubt of the formation, and none of the insolubility, of phosphate of alumina. The first point is more doubtful, though several physicians of great authority (Carpenter, Dundas, Thomson, Gibbon, Normandy) have considered its action very deleterious, and that it causes dyspepsia and constipation. Pereira considered that whatever may have been the effect in the case of healthy persons, sick persons did really suffer in that way. A question like this is obviously difficult of that strict proof we now demand in medicine. Seeing, indeed, that the usual effect of bad flour is flatulence and diarrhœa, if constipation were decidedly produced by bread, it would be more likely to proceed from alum than from any other ingredient of the bread. Looking again to the fact that sometimes bread has contained large quantities of alum,—sometimes as much as 40 grains in a 4-℔ loaf, and probably more,—we get an amount in an ordinary meal which (if the aluminium phosphate is an astringent) might very well cause constipation. Looking, then, to the positive evidence, and the reasonableness of that evidence, it seems extremely likely that strongly alumed bread does produce the injurious effects ascribed to it.

The addition of alum is forbidden by law.

Sulphuric acid is said to be added[1] before grinding instead of alum; it has the same power of preventing decay.

Sulphate of Copper.—The amount is so small that it seldom produces any symptoms; still it is possible that some anomalous cases of stomach irritation might be owing to this.

Lead.—Dr. Alford,[2] medical officer for Taunton, reports a case of poisoning from lead getting into flour. Six or seven families, including fifteen to twenty persons, suffered, some very severely. The water was analyzed, but no lead found, and then it was noted that the persons attacked all got their flour from the same mill. On making inquiries, it was found that the millstones used had (from the nature of the stone) large spaces in them, which had been filled up with lead! It was mentioned at the meeting of the sanitary authority, by one of the members, that lead was not usually employed in that way, that what was generally used was red-lead and borax, or alum and borax, both highly objectionable. If such be the case, this is another possible source of alum, which ought to be recollected.

Lolium temulentum gives rise to narcotic symptoms.

Flour from other Grains.—It is not known whether the addition of potatoes, rice, barley, peas, etc., in any way injures health, except as it may affect nutrition or digestion. Occasionally, in times of famine, other substances are mixed—chestnuts, acorns, etc. In 1835, during famine, fatal dysentery appeared in Königsberg, owing to the people mixing their flour with the pollen of the male catkin of the hazel bush. In India the use of a vetch, *Lathyrus sativus* (kassaree-dholl), with barley or wheat, gives rise to a special paralysis of the legs, when it exceeds one-twelfth part of the flour; *L. cicera* has the same effect.[3] During the siege of Paris, straw, to the extent of one-eighth, was introduced into the bread; this had a very irritating effect.

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[1] Dr. Angus Smith, Annual Report of the Manchester and Salford Sanitary Association for 1863.—Report of Sub-Committee.

[2] Sanitary Record, May 25, 1877.

[3] Dr. Irvine (Indian Annals, January, 1868) described the symptoms produced by the kassaree-dholl or *Lathyrus*. The first symptoms are gastro-intestinal irritation, and the paraplegia follows on this.

SECTION III.

BARLEY.

As an article of diet, barley has the same advantages and disadvantages as wheat. It is said to be rather laxative (Pereira), and it was noticed by the late Dr. Parkes, that either from this cause, or from the imperfect separation of the sharp husks, barley bread was particularly unsuited for dysenteric cases. It contains rather more protein bodies than wheat, and these consist of glutin-casein, glutin-fibrin, mucedin, and albumen.[1] It is certainly very nutritious, and the Greeks trained their athletes on it. Its richness in phosphoric acid and iron render it particularly adapted for this.

Choice of Barley (Scotch or pot barley, viz., the grain without the husks).—For the barley grains the same points are to be attended to as in wheat.

For the pearl barley (which is merely the grain rounded off), the best tests are the physical characters, color, freedom from dust, grit, and insects, and the test of cooking.

The patent prepared or powdered barley should be examined with the microscope ; any kind of cheaper grain may be mixed with it.

Diseases arising from Altered Quality.—These are the same as those of wheat, viz., indigestion, flatulence, and diarrhœa. There appears to be nothing peculiar in the action of diseased barley as distinguished from diseased wheat.

SECTION IV.

OATS.

Oats have been considered even more nutritious than wheat or barley, and certainly not only is the amount of nitrogenous substance great, but the proportion of fat is large. Unfortunately, the nitrogenous substance has no adhesive property, and bread cannot be made ; the amount of indigestible cellulose is large. But, on the other hand, oatmeal has the great advantage of being very readily cooked, much more so than wheat or barley. The researches of Kreusler[2] show that the nitrogenous substances of oats contain gliadin, and especially glutin-casein. This last substance is that called "avenin" by Norton and Johnstone ; it approaches very closely to the legumin of peas and beans, and is so called by Ritthausen. In nutritive properties, it causes oatmeal to stand nearer to the *Leguminosæ* than the cereals do. It contains double as much sulphur as the legumin of peas.

For this reason, and because it contains much nutriment in small bulk, because it can be eaten for long periods with relish, and keeps unchanged for a long time, it would seem to be an excellent food for soldiers during war—an opinion which does not lose in force, when we remember that it formed the staple food of one of the most martial races on record, the Scotch Highlanders, whom Jackson considered also one of the most enduring. Formerly, when oats were badly cleaned, intestinal concretions of the husk and hairs were common among those who lived on oatmeal, but these are now uncommon. It has been thought to be "heating" when taken continually, but this is probably a prejudice. The supporting qualities of oatmeal, used as a drink, made into a thin gruel, are testified to, in hard work, by the chief and divisional engineers of the Great Western Railway.[3]

[1] Ritthausen, op. cit., p. 103. [2] Ibid., p. 125.

[3] On the Issue of a Spirit Ration during the Ashantee Campaign of 1874, Appendix ii., by E. A. Parkes, M.D., F.R.S., etc., 1874.

Adulterations.—Barley-meal and the husks of barley, of wheat, and of oat itself, are added very frequently. A single look through the microscope detects the round and smooth barley starch ; the envelopes are recognized with very little more trouble. Rice and maize are also sometimes used. The drawings already given will also enable these substances to be detected. Hassall found about half the samples of oatmeal adulterated.

Choice of Oatmeal.—There should be a good proportion of envelope, but no branny character, which usually arises from barley husks ; the starch should not be discolored. A microscopic examination should always be made, both for adulterations and *Acari.*

SECTION V.

MAIZE AND RYE.

Both these grains are very nutritious. Maize contains a large quantity of yellowish fat (6 or 7 per cent.). The gluten cannot be washed out, as in wheat, though this was stated by Gorham, who found a special substance which he termed "Zeïn." This is called "maize-fibrin" by Ritthausen. It requires very careful cooking, as otherwise much passes out undigested. Dr. Johnstone noticed an outbreak of diarrhœa in a military prison clearly due to badly cooked maize. It should be soaked in water, but not too long (two to four hours), and then thoroughly boiled for several hours (four to six), at a rather low heat. Maize cakes are both palatable and nutritious.

Rye makes a very acid, dark bread, which causes diarrhœa in those unaccustomed to it. Custom, however, soon remedies this, and, as far as nutritive value goes, it appears equal to wheat. It contains less vegetable fibrin, and more casein and albumen, and a peculiar odorous substance.

Diseases connected with Maize and Rye.

It is presumed that alterations in the flour will produce the same diseases as in the analogous case of wheat. Ergotism is, however, more common in rye than any other grain. The Pellagra of Lombardy has been ascribed to a *fungus* (Verderame, or Verdet) forming in the maize. Many volumes, with different statements, have been written on this point, and it is still doubtful whether or not the Verdet has this effect. The evidence is not sufficient, but, on the whole, seems most in favor of the view which connects Pellagra with diseased maize.

SECTION VI.

RICE.

The whole grain (paddy) deprived of the husk is sold as rice. There are many varieties, of different colors (white, red, brown ?) and composition. The amount of nitrogenous matter varies greatly, from 3 to 7.5 per cent. As an article of diet, it has the advantage of an extremely digestible starch-grain, and, like the other *Cerealia,* there is a great admixture of substances ; it is, however, poorer in nitrogenous substances than wheat, and is much poorer in fat. Consequently, among rice-feeding nations, feguminous seeds are taken to supply the first, and animal or vegetable lats to remedy the latter defect. Rice is also poor in salts.

Cooking of Rice.—It should properly be steamed, not boiled, and the steaming should be thoroughly done, else the starch-grains are not swollen and digestible. If boiled, it should not be for too long a time, otherwise

the rice (or conjee) water contains some albuminous matter, and the grain loses in nutritive power.

Choice of Rice.—The grains should be clean, without grit; the individual grains without spots or evidence of insects. The size varies much, according to the kind; the large kinds usually command the highest market price.[1]

Comparison of the foregoing Grains—Order of Richness.

Nitrogenous Substances.	Fat.	Starch, etc.	Salts.
Wheat.	Maize.	Rice.	Barley.
Barley.	Oats.	Maize.	Oats.
Rye.	Barley.	Wheat.	Wheat.
Oats.	Rye.	Rye.	Rye.
Maize.	Wheat.	Oats.	Maize.
Rice.	Rice.	Barley.	Rice.

SECTION VII.

MILLET, RAGGY, BUCKWHEAT.

Various other grains belonging to the *Cerealia*, or to other natural orders, but having similar properties, are used as food in different countries. Of these, the above-named are chiefly those the medical officer may have to report on.

Millet is used largely in Africa (west coast) and Algeria, in Italy, Spain, Portugal, some parts of India, China, etc.

English Names.	Botanical Names.	Indian Names.
Common millet,	*Panicum miliaceum,*	Sawee Chennawaree (Hindustani). Varagoo (Tamul).
Small millet,	*Sorghum* or *Panicum vulgare,*	Dhurra (Arabic). Cholam (Tamul). Joar or Jowree (Hind.).
Spiked millet,	*Pencillaria spicata,*	Bájra or Bajree (Hind.). Cumboo (Tamul).
Golden-colored millet,	*Sorghum saccharatum.*	
Italian millet,	*Setaria Italica,*	Kala kangnī (Hind.). Tenay (Tamul).
German millet,	*Setaria Germanica.*	
	Eleusine corocana,	Raggee or Raggy (Hind., Canarese, and Tamul). Murha and Maud in the N. Prov. of Hindustan.[2]

The millets are very similar in composition (as given in the table, p. 212). The ash is rich in silica and phosphates.

[1] The larger grains—especially the American kinds—have often much less flavor than the smaller and less attractive Indian kinds.

[2] The native names of the Indian grains and pulses used, especially in Southern India, are given very fully in a paper by Mr. Elliot (Edinburgh Philosophical Journal, July, 1862); and also in Mr. Cornish's excellent paper (Madras Medical Journal, February, 1864).

Millet bread is very good, and some was issued to the troops in the last China Expedition. This should always be done in a millet country, if wheat or barley cannot be got. In Northern China millet is almost exclusively used.

Raggy or Ragee, Murha and Maud of the upper provinces (*Eleusine corocana*), is largely used in Southern India (Mysore), and in some parts of Northern Hindustan, and is considered even more nutritive than wheat. It is very indestructible, and can be preserved for many years (even sixty) in dry grain pits.

Buckwheat is not so likely to be used. It is poor in nitrogenous substances and fat, but makes a fair tasting bread.

SECTION VIII.

LEGUMINOSÆ.

The *Leguminosæ*, in respect of dietetic properties, are broadly distinguished from other vegetables by their very large amount of nitrogenous substance, called legumin or vegetable casein; there are, in addition, a little albumen and other protein bodies. The advantages of peas and beans as articles of diet are the great amount of legumin, and the existence of much sulphur and phosphorus in combination with the legumin; in salts also they are a little richer than the *Cerealia*, especially in potash and lime, but are rather poorer in phosphoric acid and magnesia; 1 ℔ of peas contains about 168 grains of salts. The disadvantage of peas and beans is a certain amount of indigestibility; about 6.5 per cent. of the ingested pea passes out unchanged, and starch-cells, giving a blue reaction with iodine, are found in the fæces; much flatus is also produced by the hydrogen sulphide formed from the legumin. Still, they are a most valuable article of food, and always ought to be used when much exercise is taken, as they are an excellent addition to meat and *Cerealia*. Both men and beasts can be nourished on them alone for some time. Added to rice, they form the staple food of large populations in India. Mr. Cornish mentions that, in the Sepoy Corps, the men are much subject to diarrhœa from the too great use of the "dholl" (*Cajanus indicus*). Gram (*Cicer arietinum*), although chiefly used for horses and cattle, is sometimes employed as food for men in India; it makes palatable and nutritious cakes.

Choice of Pea.—By keeping, peas lose their color, become very pale and much shrivelled, and extremely hard. Anything like decomposition, or existence of insects, is at once detected. The powder does not keep very long; the whole peas should be split. The microscope should be used to detect *Acarus*.

Cooking of Peas and Beans.—They must be boiled slowly, and for a long time, otherwise they are very indigestible. If old, no amount of boiling softens them; in fact, the longer they are boiled the harder they become; they should then be soaked in cold water for twenty-four hours, crushed, and stewed; in this way even very old peas may be made digestible and palatable. Chalk-water must be avoided in the case of peas as of other vegetables, as the lime-salts form insoluble compounds with the legumin.

Lathyrus sativus (Kassaree-dholl of India).—Occasionally in Europe, and constantly in some parts of India, this vetch has been used when mixed with wheat or barley flour for bread. When used in too great quantities, it produces (without there being necessarily any alteration of the grain ?) constipation, colic, and some form of indigestion, and if eaten in large quantity, paraplegia. It is also injurious to horses, but less so to oxen.

In Bengal, Dr. Irvine [1] found in some villages no less than from 10 to 15 per cent. of the people paralytic from this cause. From its composition, it would not appear to be innutritious.

SECTION IX.

STARCHES [2] AND SUGAR.

Sub-Section I.—Arrowroots.

Maranta Arrowroot (West Indian).—The chief kind is obtained from *Maranta arundinacea.* The quality of *Maranta* arrowroot is judged of by its whiteness ; by the grains being aggregated into little lumps, and by the jelly being readily made, and being firm, colorless, transparent, and good tasted. The jelly remains firm for three or four days without turning thin or sour, whereas potato flour jelly in twelve hours becomes thin and acescent. Under the microscope, the starch-grains are easily identified. They are slightly ovoid, like potato starch, but have a mark or line at the larger end (the hilum of the potato starch is at the smaller end), the concentric lines are well marked. The most common adulterations are sago, tapioca, and potato starch. All these starch-grains are readily detected by the microscope.

Curcuma Arrowroot.—Arrowroot obtained from *Curcuma* has the same physical characters as *Maranta,* but under the microscope the starch-grains are large and oblong, marked with very distinct concentric lines, which, however, are not entire circles, having an indistinct hilum at the smaller end.

Manihot Arrowroot.—This comes from Rio, and is obtained from *Jatropha manihot.* The starch-grains are very marked.[2]

Tacca or *Otaheiti Arrowroot.*—Hassall gives a figure which shows that the starch-grains resemble those of *Manihot.*

Arum Arrowroot.—The Arum or Portland arrowroot has small, angular, and facetted starch-grains, which cannot be confounded with any of the former. They are a little like maize. This is sometimes called Portland Sago.

British or *Potato Arrowroot.*—Under the term "Farina," potato starch is sold in the market ; so white and crackling, and making so good a jelly, that it is not always easy to distinguish it from *Manihot.* The microscope at once detects it. The pear-shaped grains, marked hilum toward the smaller end, and the swelling with weak liquor potassæ, render a mistake impossible. In making the jelly a much larger quantity is required than of Maranta arrowroot. *Maranta arundinacea,* mixed with twice its weight of hydrochloric acid, produces a white opaque paste, whereas potato starch treated similarly produces a transparent acid jelly-like paste.

Canna or Tous-les-Mois *Arrowroot,* obtained from *Canna edulis,* N.O. *Marantaceæ.*—The starch-grains are like those of the potato, but much larger, and the concentric lines are beautifully marked and distinct.[2]

Sub-Section II.—Tapioca.

This is obtained from the finest part of the pith of *Jatropha manihot* or *Cassava.*

Under the microscope the starch-grains are small, with a central hilum ; and sometimes three or four adhere together and form compound grains.

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[1] Indian Annals, 1857. Ibid., January, 1868, p. 89, Dr. Irvine notices the resemblance of the symptoms to the Barbiers of Bontius.

[2] See table, p. 273, and plate of drawings by Dr. Maddox farther on.

It is adulterated with sago and potato starch, both of which are easily detected by the microscope.

Sub-Section III.—Sago.

The best kinds are derived from the sago palm (*Sagus farinifera*), but the sago of the *Cycas circinalis* is also sold; it is, however, inferior.

Granulated sago is either "common" or "pearl;" the latter is chiefly used in hospitals. The starch is soluble in cold as well as in hot water. The starch-grains are elongated, rounded at the larger end, and compressed at the other; and hence their shape is quite different from the potato starch. The hilum is a point, or more often a cross, slit, or star, and is seated at the smaller end; whereas, as in Maranta arrowroot, the hilum is at the larger end. Rings are more or less clearly seen.

In the market is a fictitious sago made of potato flour. This is sometimes colored red or brownish, either from cochineal or sugar. In thirty specimens Hassall found five to be fictitious. The microscope easily detects potato starch.

It is sometimes difficult to remember the characters of the different forms of starch, but it may be to a certain extent facilitated by a tabulated arrangement. The following table has been compiled by Dr. J. D. Macdonald, R.N., F.R.S.

Microscopical Discrimination of the Principal Arrowroots and Starches.

I. *Starches* with isolated smooth or unfacetted grains, being originally free in the cell cavity.

	General Characters.		Particular Characters.		Name.
	Form.	*Hilum.*	*Form.*	*Hilum.*	
Unfacetted.	A.—Contour ovoid. *Hilum* eccentric.	Grains large. *Hilum* at the small end.	Outline even. Continuous rings, oblique, including more than half the grain.	*Hilum* distinct.	Potato; British arrowroot.
			Outline even. Continuous rings, nearly transverse, including less than half the grain.	*Hilum* distinct.	Tous-les-mois (*Canna*) arrowroot.
				Hilum indistinct.	*Curcuma* arrowroot.
		Grains medium sized. *Hilum* at the larger end.	Outline uneven, often with beak-like projections.	*Hilum* slit-like, triradial or crucial.	Bermuda (*Maranta*) arrowroot.
			Outline more even, beak less frequently seen.	*Hilum* similar, but less apparent.	St. Vincent arrowroot.
			Whole grain still smoother and more regular.	*Hilum* similar, but still less marked.	Natal arrowroot.
	B.—Contour oval.	*Hilum* longitudinal, linear lateral.	Grains often broad and reniform.	*Hilum* cleft-like, puckered, irregular.	Bean starch.
			Grains narrower and more uniform.	*Hilum* less puckered and more regular.	Pea starch.
	C.—Contour round.	*Hilum* central.	Form lenticular.	Surface convex at the *hilum*. Grains large and minute only.	Wheat starch.
				Surface depressed at the *hilum*. Grains large, medium-sized, and minute.	Barley starch.
			Form spherical.	*Hilum* often deeply fissured, star-like.	Rye starch.

II. *Starches* with the grains facetted by original juxtaposition in the cell cavity. *Hilum* central.

Facetted.	A.—Often presenting the rounded free surface of grains originally superficial in the cluster.	*Hilum* often cavernous.	Grains very large, with a central sinus or cavernous antrum. (Rings sinuous, irregular.)		Sago.
			Grains small. (Sago in miniature.)		Tapioca.
		Hilum stellate.	Grains small. (Like Tapioca without preparation.)		Rio arrowroot.
	B.—Altogether facetted.	*Hilum* stellate.	Grains small. (Discoidal with facetted margin.)		Maize.
		Hilum inconspicuous.	Grains minute.	In rounded glomeruli or compound grains, and free in the cells.	Oats.
				Closely packed in the cells, and fixed.	Rice.

Sub-Section IV.—Sugar.

Choice and Examination.—The sugar should be more or less white, crystalline, not evidently moist to the touch, and should dissolve entirely in water, or leave merely small fragments, which on examination with the microscope will be found to be bits of cane. The whiter the quality the less is the percentage of water, which varies in different kinds of sugar, from about .25 per cent. (in the finest sugar) to 9 or even 10 per cent. (in the coarser brown sugars). Most of the sugar now sold is very good and pure.

The unpurified sugars contain albuminous matters which decompose, and a sort of fermentation occurs. *Acarus*, or the sugar-mite, is usually found in such sugar, which is not known to be hurtful. *Fungi* also are very frequently present.

Method of Examination.

1. Determine physical characters of color, amount of crystallization, etc.
2. Dissolve in cold water; fragments of cane, starch, sand, gypsum, calcium phosphate are left behind; test with iodine for starch. The best way is to dissolve under the microscope, as all adulterations are then at once detected.
3. Determine percentage of water by drying thoroughly 10 grammes, and again weighing.
4. Excess of glucose (a little is always present) is detected by the large immediate action on the copper solution.

SECTION X.

SUCCULENT VEGETABLES.

Almost all other vegetables (except potatoes) are used, not so much on account of nutritive qualities, as for the supply of salts ; some of them, however, contain very digestible starch and sugar, or other substances, such as pectin or asparagin, or peculiar oils which act as condiments, as in onions.

SUB-SECTION I.—POTATOES (*Solanum tuberosum*).

The potato contains only a small amount of nitrogenous matter, and hardly any fat. Its ash is also poor in potash and phosphoric acid. But its starch is very digestible, and it contains a large quantity of vegetable acids and their salts (malates? tartrates? citrates), which form carbonates on incineration. The juice is acid, and there is no better anti-scorbutic. The acids are combined with potash, soda, and lime.

As the amount of salts is small, and that of water large, at least 8 to 12 ounces of potatoes should be taken daily if no other vegetables are eaten (= 8 ounces at 1 per cent. of salts contain 35 grains ; at 1.5 per cent. = 52.5 grains).

Choice.—Potatoes should be of good size, firm, cut with some resistance, and present no evidence of disease or *fungi.*

A still better judgment may be formed by taking the specific gravity, and using the following tables : Multiply the specific gravity by the factor opposite it, and divide by 1,000 ; the result is the percentage of solids :—

Specific gravity, between	Factor.	Specific gravity, between	Factor.
1061–1068	16	1105–1109	24
1069–1074	18	1110–1114	26
1075–1082	20	1115–1119	27
1083–1104	22	1120–1129	28

If the starch alone is to be determined, deduct 7 from the factor, and proceed as before, the result is the percentage of starch.

If the specific gravity of the potato is—

Below 1068,	the quality is	very bad.
Between 1068–1082,	"	inferior.
Between 1082–1105,	"	rather poor.
Above 1105,	"	good.
Above 1110,	"	best.

As, however, the medical officer will seldom have an hydrometer [1] which will give so high a specific gravity, and must work, therefore, with a common urinometer, the following plan must be adopted :—Take a sufficient quantity of water, and dissolve in it $\frac{1}{2}$ an ounce or an ounce of salt, and take the specific gravity ; then add another $\frac{1}{2}$ ounce or ounce, and take again the specific gravity ; do this two or three times, so as to get the increase of specific gravity for each addition of a known quantity of salt ; then add salt enough to bring the specific gravity to the desired amount. This is, of course, not quite accurate, but in the absence of proper instruments it is the only plan that seems feasible.

Cooking of Potatoes.—The skins should not be taken off, or a large amount of salts passes into the water ; using salt water is a good plan, as

[1] Baumé's or Twaddell's hydrometers are the best for the purpose.

fewer of the salts then pass out. The boiling must be complete, as the starch-grains are otherwise undigested, and it must be slow, else the cellulose and albuminates are hard. Steaming potatoes is by far the best plan; the heat must be moderate; the steam penetrates everywhere, and there is no loss of salts.

Preservation of Potatoes.—Sugar, in the form of molasses, is the best plan on a large scale; a cask is filled with alternate strata of molasses and peeled and sliced potatoes. On a small scale, boiling the potatoes for a few minutes will keep them for some time. Free exposure to air, turning the potatoes over and at once removing those that are bad, are useful plans.[1]

The preserved potatoes are sliced, dried, and granulated, and when well prepared, are extremely useful.

The Sweet Potato and the Yam are somewhat similar to the ordinary potato, and form good substitutes when potatoes cannot be obtained.

Sub-Section II.—Other Vegetables.

The composition of Carrots and Cabbage has been already given. The composition of the other kinds of vegetables is similar.

Some vegetables contain special ingredients, such as asparagin in asparagus (a small amount is also contained in potatoes), wax, pectin, which is a little more oxidized than starch or sugar; or peculiar oils and savory or odoriferous matters.

On account of its volatile oils, the onion tribe is largely used, and is a capital condiment, and has an effect as an anti-scorbutic. It contains some citrate of calcium.

There are many vegetables which can be employed as anti-scorbutics besides potatoes, onions, and green vegetables. The wild artichoke and *Agave americana* (cactus) are both excellent anti-scorbutics, and the latter is said to be better than lime-juice. Sorrel, and in a less degree scurvy-grass and mustard and cress, are useful. In New Mexico, a salad made of the "lamb's quarter" (*Chenopodium album*) has been found very useful.[2]

In war almost any kind of vegetables may be used rather than that the troops should be left without such food. In one of the Caffre wars, an African corps kept free from scurvy by using a sort of grass (?) in their soup.

The dried vegetables, and especially the dried potato, have considerable anti-scorbutic powers (Armstrong).[3] The dandelion was largely used in the French army in the Crimean war. The American Indians put up for winter quantities of dried plums, buffalo berries, and choke berries, and thus escape scurvy.[4]

If vegetables cannot be procured, citric acid, or citrate, tartrate, and lactate of potassium should be given. These can be carried as lozenges.

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[1] In the Crimean war there was a considerable loss of potatoes sent up to Balaklava, and at a time when the men were most in need of them. The addition of sugar to the raw potatoes might have been made.

[2] Mil. Med. and Surg. Essays prepared for the U. S. Sanitary Com., 1864, p. 202.

[3] Naval Hygiene, p. 112. In the American war, however, the anti scorbutic effects of the dried vegetables were not found to be very great. I found that, in a sound raw potato, the amount of free and combined acid (reckoned as citric) was 0.4503 per cent.; and that in the preserved potato used in the Arctic Expedition (1875–76) it was 1.085; or in the ratio of 1 to 2.4. From this we find that 7 ounces of the preserved potato contained the equivalent of 31½ grains of citric acid, or one ounce of navy lime-juice. The ration usually issued (2 to 4 ounces) is, therefore, too small, unless other anti-scorbutics be given. (See Report of Committee on Scurvy, Appendix, xiii., 365.)—[F. de C.]

[4] Hamilton's Mil. Surg., p. 212.

SECTION XI.

COW'S MILK.

A cow gives very variable quantities of milk, according to food and race, and age of the calf ; perhaps 20 to 25 pints in twenty-four hours is the average for the year, but with poor feeding it will fall much below this ; occasionally a cow, soon after calving, will give 50 pints, but this is not common. A goat will give 6 to 8 pints.

Sub-Section I.—Milk as an Article of Diet.

Milk contains all the four classes of aliment essential to health. Being intended especially for feeding during growth, the proportions of nitrogenous substances and fat, as compared to sugar, are large.

For the average composition of good milk, see table, p. 212.

In addition to casein, a small quantity of true albumen remains in solution after the casein has been thrown down ; and there is also, according to Millon,[1] another albuminoid substance, which he calls lactoprotein. In cow's milk the amount of albumen is said to be 5.25 grammes per litre ; the amount of lactoprotein is much smaller, but has not been precisely determined.[2]

The amount of salts varies from .5 to .8 per cent., but seldom, if ever, exceeds 1 per cent. The usual average is about 0.7 to 0.75. This is of importance in the detection of adulteration by salts. In poor milk the salts may be as low as .3 per cent.

Milk is very largely used in some countries, especially in India and Tartary, where the use of the koumiss, prepared from mare's milk, has been supposed to prevent phthisis. This fermented drink is now also prepared from cow's milk, and largely used in this country.

Milk varies in quantity and composition according to—1st, the age of cow ; 2d, the number of pregnancies, less milk being given with the first calf (Hassall) ; 3d, to the age of the calf, being at first largely mixed with colostrum ; 4th, to the kind of feeding, beet and carrot augmenting the sugar ;[3] 5th, and remarkably according to the race, some cows giving more fat (as Alderneys), others more casein (as the long-horns). The last portion of the milk given in milking is richest in cream (Hassall).

Wanklyn states that the proportion of solids is more stable, and never falls below 11.5 per cent. In Sweden, the milk of a herd of cows being analyzed daily for a year, the solids never fell to 11.5, and only 4 times to 12 per cent. (Wanklyn).

The goat's milk is rather richer in solids (14.4 per cent.—Payen), and contains also a peculiar smelling acid (hircin or hircic acid). Specific gravity, 1032-1036.

Ass's milk is rather poorer in solids (9.5 per cent.—Payen). This is owing to a small amount of casein and fat ; it is rich in lactin. The specific gravity varies from 1023 to 1035.

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[1] Comptes Rendus, t. lix , p. 396.

[2] Commaille (Comptes Rendus, November 9, 1868) found creatinin in some putrid milk, derived, he thinks, from creatin. He admits also, after Lefort, that there is a little urea. He found also some organic acids, the nature of which is doubtful.

[3] Some observations of Dr. Subbotin (Virchow's Archiv, Band xxxvi., p. 561) on the milk of bitches, show a marked effect by food ; the fat was much increased by meat; the casein was less affected ; a large quantity of fat greatly lessened the secretion.

The buffalo milk is richer in all the ingredients.

Taking the total solids of cow's milk at 13.2 per cent. (specific gravity 1030), one pint (20 ounces) will contain, in round numbers—

Casein	350	grains.
Fat	324	"
Lactin	420	"
Salts	66	"
Total	1,160	

or more than $2\frac{1}{2}$ ounces avoir. of water-free food.

To give 23 ounces of water-free food (or one day's allowance for an adult), about 9 pints of milk, of specific gravity 1030, are necessary. For an adult this would be far too much water, and the albuminates and fat would be in great excess. But for the rapid formation and elimination of the young, the water and fat are essential. It is a question whether, in old age, large quantities of milk might not be a remedy for failures in tissue formation and elimination.[1]

Sub-Section II.—Alterations of Milk.

The cream rises in from four to eight hours ; it is hastened by adding warm water, but its quantity is not increased (Hassall). A new apparatus has been recently introduced by which the cream is obtained by agitation in a few minutes.

Milk alters on standing ; it absorbs oxygen, and gives off CO_2 ; placed in contact with a volume of air greater than its own bulk, it absorbs all the oxygen in three or four days (Hoppe-Seyler). The CO_2 is formed at the expense of the organic matter (probably casein—Hoppe-Seyler), and bodies richer in carbon and hydrogen are formed ; fat increases in amount, and oxalic acid is said to be formed.

Subsequently lactic acid is formed in large quantities from the lactin ; the milk becomes turbid, and finally casein is deposited. The cream which had previously risen to the surface disappears.

Milk given by Diseased Cows.

Milk from diseased animals soon decomposes ; it may contain colostrum, or heaps of granules collected in roundish masses, pus-cells, or epithelium, and occasionally blood. It then soon becomes acid, and the microscope usually detects abnormal cell-forms, and casts of the lacteal tubes.

In cattle plague, it is said by Husson that the lactin lessens, while the nitrogenous matters are increased, and blood and aggregated granules are seen under the microscope. In foot-and-mouth disease the specific gravity rapidly falls (from 1030 to 1024), though this is not invariable ; there are granular heaps under the microscope, and often blood or pus-cells ; Mr. M'Bride says pus can be found for a month after recovery. *Bacteria* and small oval and round cells are common.[2] The milk sometimes coagulates on boiling.

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[1] This was a point debated by Galen, so old is this suggestion. It is still undecided. Some old persons cannot digest milk.

[2] Figures of the microscopical appearances are given in some very good papers on the subject in the British Medical Journal, October, 1869.

Sub-Section III.—Examination of Milk.

This is intended first to determine the quality. Put some of the milk in a long glass, which is graduated to 100 parts ; a 100 centimetre or litre measure will do, or a glass may be specially prepared by simply marking with compasses 100 equal lines on a piece of paper, and gumming it on the glass. Allow it to stand for twenty-four hours in a cupboard secured from currents of air. By this means the percentage of cream can be seen, and the presence of deposit, if any, observed. There should be no deposit till the milk decomposes; if there be, it is probably chalk or starch.

The cream should be from $\frac{6}{100}$ths to $\frac{11}{100}$ths ; it is generally about $\frac{8}{100}$ths; in the milk of Alderney cows it will reach $\frac{30}{100}$ths or $\frac{40}{100}$ths. The time of year (as influencing pasture), and the breed, should be considered.

While this is going on, determine—

1. *The Physical Characters.*—Placed in a narrow glass, the milk should be quite opaque, of full white color, without deposit, without peculiar smell or taste. When boiled it should not change in appearance.

2. *Reaction.*—Reaction should be slightly acid or neutral, or very feebly alkaline ; if strongly alkaline, either the cow is diseased (?) or there is much colostrum, or sodium carbonate has been added.

3. *Specific Gravity.*—The specific gravity varies from 1026 to 1035, A very large quantity of cream lowers it, and after the cream is removed, the specific gravity may rise, under ordinary circumstances, about 2°.[1] The average specific gravity of unskimmed milk may be taken as 1030 at 60° Fahr., and the range is nearly 4° above and below the mean. It varies with temperature, so that in the tropics the medical officer will have to allow for this difference. The following are the relative degrees of a milk that shows 1030 at 60° Fahr., and 1031 at 39° Fahr. (maximum density-point of water):—

Temperature of Milk,	39° F. = 1031	Temperature of Milk,	80° F. = 1027.5
" "	60° F. = 1030	" "	90° F. = 1025.8
" "	70° F. = 1029	" "	100° F. = 1024.0

The addition of water may be detected by the specific gravity. At 60° Fahr. there is a loss of 3° for every 10 per cent. of water added. No doubt the method is not perfect, but its ease of application strongly recommends it.

4. *Examine Chemically for the Amount of the Different Constituents.*

(*a*) *Total solids.*—Evaporate a known quantity to dryness in a flat and shallow dish, and weigh. Calculate the percentage. The heat must not

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[1] Dr. Davies records a case where the specific gravity was 1024.6 ; there was 17 per cent. of cream, and the solids were 16.25. A case of this kind cannot mislead if the amount of cream is determined. Davies recommends that the specific gravity of the whey should be taken ; he says it is very constant between 1026 and 1028.

In one sample I examined the specific gravity was 1020, and the cream $\frac{40}{100}$, the specific gravity of the skimmed milk was 1028.9. Another sample gave—specific gravity 1017.6, cream $\frac{20}{100}$; specific gravity of skimmed milk, 1032.75. Another sample (which purported to be the same as the last) gave a specific gravity of 1018.84, but the cream was only $\frac{4}{100}$; in this case the greater part of the cream had been removed, and about 50 per cent. of water added.—(F. de C.)

exceed 212° Fahr. (100° C.), and should be continued for at least three hours. There should be no charring.

(*b*) *Ash.*—Incinerate the dried solids, and weigh.

(*c*) Determine the amount of *fat*. This is best done by means of the fat apparatus of Gerber or of Soxhlets, in which ether is made to pass repeatedly through the dried solids and carries with it the fat. The ether is then evaporated and the fat weighed. An approximate result can be given by the employment of an instrument called a lactoscope, which measures the degree of transparency. The lactoscope of Donné has been improved by Vogel, as a simple plan for ascertaining the amount of fat in milk.[1]

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[1] Vogel's instrument consists of a little cup, formed by two parallel pieces of glass, distant $\frac{1}{2}$ a centimetre (= .1968 inch, say $\frac{2}{10}$ths of an inch) from each other, and closed everywhere except at the top, so as to form a little vessel; a glass graduated to 100 C.C., and a little pipette, which is divided to $\frac{1}{2}$ C.C., are also required. Water (100 C.C.) is placed in the measure, and 2 or 3 C.C. of milk (which should be at first agitated, so as to mix any separate cream) are added to it. The parallel glass cup is then filled with this diluted milk, and a candle placed about one metre from the eye (= 39.37 inches) is looked at in a rather darkened room; if the flame of the candle is seen, the milk is poured back into the large measure; more milk is added to it, and it is poured again into the parallel glass, and the light is again looked at; the experiment ends when the contour of the light is completely obscured. The candle should be a good one, but the difference in the amount of light is not material. The percentage amount of fat in the milk is then calculated by the following formula (which has been determined by a comparison of the results of the instrument, and of chemical analysis): x being the quantity of fat sought, and m the number of C.C. of milk which added to the 100 C.C. of water suffice to obscure the light.

$$x = \frac{23.2}{m} + 0.23.$$

If, for example, 3 C.C. of milk, added to the 100 of water, were sufficient to obscure the light, the percentage of fat is:

$$x = \frac{23.2}{3} + .23 = 7.96 \text{ per cent.}$$

From this formula the following table has been calculated, which enables us to read off at once the percentage of fat:—

C.C. Milk.	=	Per cent. of Fat in the Milk.	C.C. Milk.	=	Per cent. of Fat in the Milk.
1 to 100	of water obscures the light =	23.43	14 to 100	of water obscures the light =	1.88
1.5	“ “	15.69	15	“ “	1.78
2	“ “	11.83	16	“ “	1.68
2.5	“ “	9.51	17	“ “	1.60
3	“ “	7.96	18	“ “	1.52
3.5	“ “	6.86	19	“ “	1.45
4	“ “	6.03	20	“ “	1.39
4.5	“ “	5.38	22	“ “	1.28
5	“ “	4.87	24	“ “	1.19
5.5	“ “	4.45	26	“ “	1.12
6	“ “	4.09	28	“ “	1.06
6.5	“ “	3.80	30	“ “	1.00
7	“ “	3.54	35	“ “	0.89
7.5	“ “	3.32	40	“ “	0.81
8	“ “	3.13	45	“ “	0.74
8.5	“ “	2.96	50	“ “	0.69
9	“ “	2.80	55	“ “	0.64
9.5	“ “	2.67	60	“ “	0.61
10	“ “	2.55	70	“ “	0.56
11	“ “	2.43	80	“ “	0.52
12	“ “	2.16	90	“ “	0.49
13	“ “	2.01	100	“ “	0.46

If, for example, 1 cubic centimetre of milk to 100 of water obscures the light, the

(*d*) *Casein.*—Take a weighed or measured quantity; add two or three drops of acetic acid, and boil. Add a good deal of water; allow to stand for twenty-four hours; pour off the supernatant fluid; wash the precipitate well with ether at 80°; dry, and weigh. Calculate the percentage. It is difficult to free it entirely from fat. Wanklyn recommends the albuminoid ammonia process, as in the case of nitrogenous matter in water: 1 part of casein yielding 0.065 of ammonia. The determination is not often required.

(*e*) Determine the amount of *lactin* by the saccharometer, or by the standard copper solution.[1] To do this, take 10 C.C. of milk, add a few drops of acetic acid, and warm—this coagulates the casein with the fat; then make up to 100 C.C. with distilled water, filter, and put the filtered whey (which ought to be as clear as possible) into a burette. Take 10 C.C. of standard copper solution, put it in a porcelain dish, and add 20 or 30 C.C. of distilled water; boil; as soon as it is in brisk ebullition drop in the whey from the burette; take care that the liquid is boiling all the time; continue the process until the copper is all reduced to red suboxide and no blue color remains in the supernatant liquid; but stop before any yellow color appears. Read off the amount of whey used, and divide by 10; the result is the amount of milk which exactly decomposes 10 C.C. of the copper solution. The 10 C.C. of the copper solution are equal to .0667 gramme of lactin. The amount of lactin in the 10 C.C. of milk is then known by a simple rule of three; and the amount in 100 C.C. of milk is at once obtained by shifting the decimal point one figure to the right.

Example:—15 C.C. of diluted whey were required to reduce the 10 C.C. of copper solution; $\frac{15}{10} = 1.5$ the amount of original milk; $0.0667 \div 1.5 = 0.0445$ gramme of lactin in 1 C.C.; therefore $0.0445 \times 100 = 4.45$ per cent.

5. *Examine the Milk microscopically.*—The only constituents of milk are the round oil globules of various sizes in an envelope and a little epithelium. The abnormal constituents are epithelium in large amount, pus, conglomerate masses, and casts of the lacteal tubules. The added ingredients may be starch-grains, portions of seeds, and chalk (round and often highly refracting bodies, with often a marked double outline, and at once disappearing in acid). Colostrum, occurring for three to eight days after the birth of the calf, is composed of agglomerations of fat vesicles united by a granular matter. *Infusoria* are sometimes found in milk, and *fungi* (*Oidium lactis* and *Penicillium*) are so almost invariably, if the milk has been kept.[2]

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percentage of fat is 23.43; if 8 cubic centimetres, added to 100 of water, are needed to obscure the light, the percentage is 3.13, etc.; so that in four or five minutes an approximate analysis of the milk is made, as far as the fat is concerned.

Wanklyn states that 0.2 gramme of fat equal 1 gramme of cream.

[1] See Appendix A., Vol. II. Wanklyn recommends dissolving out the lactin from the solids (after the fat is removed) by means of alcohol, evaporating and weighing; then incinerating; the difference gives the amount of lactin. This seems on the whole less convenient for the medical officer than the copper test. Macnamara (Indian Medical Gazette, 1873) uses alcohol for extracting the lactin, but determines it by Fehling's copper test.

[2] Dr. Willard of Cornell University notes the experience of Professor Law, who observed a peculiar ropy material in milk, and traced it to cows drinking stagnant water containing organisms similar to those found in the milk; a drop of this water, put into good milk, soon developed these organisms. The cows were feverish.—(Dr. John Ogle, Journal of the Agricultural Society, November 15, 1872; Lancet, October 11, 1873.)

Scheme for a Short Examination.

As a medical officer is constantly called upon to examine milk, and will seldom have time to go thoroughly into all the points just noted, the following short scheme will be useful :—

1. Put some milk into the long graduated glass for deposit, and for determining percentage of cream.[1]

2. Take physical characters, reaction, and specific gravity. Take specific gravity of the whey, if there be time to do this.

3. Determine fat by Vogel's milk-test.[1]

4. Examine the milk with the microscope. The comparison of the specific gravity, and the amount of cream which rises, or of fat, will be found to give, in conjunction with the physical characters, a very good idea of the quality of the milk.

SUB-SECTION IV.—PRESERVATION OF MILK.

1. Boiled, the bottle quite filled, and at once corked up and well sealed, the milk lessens in bulk, and a vacuum is formed above. It will keep for some time. A little sugar aids the preservation. If the heat is carried in a close vessel to 250° Fahr., the milk is preserved for a long time, even for years; the butter may separate, but this is of no consequence.

2. Sulphur dioxide passed through it, or sodium sulphite added. This may be done after boiling.

3. A little sodium carbonate and sugar added, with or without boiling. This will keep for ten days or a fortnight.

4. The addition of salicylic acid, borax, boracic acid, or boroglyceride (Barff's patent).

In the market are—milk in tins, preserved in the usual way by exclusion of air, concentrated milk mixed with sugar, and desiccated or dried milk. This last is milk carefully dried at a low temperature, with a little sugar. Dissolved in water, it forms an excellent milk.

The preserved liquid milk often has the butter separated; if so, it may be spread on bread. It is not easy to remix it with milk, but it is said that the separation may be prevented by adding a little yolk of egg.

SUB-SECTION V.—ADULTERATIONS.

1. *Water.*—This is extremely common, and is, in fact, generally the only adulteration; it is best detected by specific gravity or by the amount of solids by evaporation. Wanklyn suggests the amount of ash as a good test of watering; the normal ash being, according to him, about 0.73 per

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[1] Macnamara (Indian Medical Gazette, 1873) finds that the cream is not very useful in India as a test, the rapid coagulation of the milk preventing it rising; similarly Vogel's test does not give satisfactory results. It would, therefore, be necessary to determine the constituents by the chemical methods if possible. The following plan may be adopted: Measure out carefully two portions of milk, and evaporate both to dryness: weigh: from this the *total solids* may be obtained. Then incinerate one portion: weigh: this gives the *ash*. Exhaust the other with ether in Gerber's or Soxhlet's apparatus: from this the *fat* may be obtained. Exhaust the residue with alcohol; this gives the *lactin*, which may be determined either by weighing or incineration, or by Fehling's process; weigh the residue, then incinerate it, and weigh again: the difference will be the *casein*. The last weighing also gives a controlling determination of the ash.

cent. In this case the calculation would be as follows:—Let (a) be the observed percentage of ash and (A) the normal amount: then $100 - \frac{100a}{A} =$ per cent. of water added: let (a) $= .50$, and A $= .73$: then $100 - \frac{100 \times .50}{.73} =$ 31.5 per cent. of water added. In a similar way the amount of "solids not fats" may be used as a standard.

2. *Starch, dextrin,* or *gum,* to conceal the thinness, and the bluish color produced by water. Not a common adulteration. Add iodine at once for starch; boil with a drop of acetic acid, and add iodine for dextrin, or add acetate of lead and then ammonia, a white precipitate falls.

3. *Annatto* or *turmeric* is added to give color. Liquor potassæ at once detects turmeric.

4. *Emulsions* of seeds (*hemp* or *almond*), added; this is uncommon. Boil. The albumen of the seeds coagulates; the milk will not mix with tea. Hemp seed gives an unpleasant odor to the milk (Normandy).

5. *Glycerin* has been sometimes met with. The milk will be sweeter than usual, and there will be a difficulty, if not impossibility, in drying the solids by evaporation.

6. *Chalk,* to neutralize acid, and to give thickness and color. Let it stand for deposit; collect and wash deposit, and add acetic acid and water; after effervescence, filter, and test with oxalate of ammonium.

7. *Sodium Carbonate.*—Very difficult of detection unless the milk be alkaline. Determine the ash, and see if it effervesces; if so, either some carbonate has been added, or if the sodium have united with lactic acid, this will be converted into carbonate, and enough lactic acid to give an effervescing ash does not exist in good milk.

8. Milk is often *boiled* to preserve it; it may then take up from the vessel lead, copper, or zinc, if these metals are used.

Cream is adulterated or made with magnesium carbonate, tragacanth, and arrowroot. The microscope detects the latter, and particles of magnesium carbonate (round) can also be seen, and found to disappear with a drop of acid. It is also said that yolk of egg is added both to cream and milk.[1]

In most cases of falsification, milk is *watered* or *creamed*, or both *creamed* and *watered*. *Watering* alone is detected by a lowered specific gravity and a diminished quantity of cream. *Creaming* alone is detected by a heightened specific gravity and a diminished quantity of cream. When both are resorted to, the cream will be small in amount, but the specific gravity may be normal. When a quantitative analysis can be made, watering alone is indicated by a general lowering of the constituents, which, however, preserve their normal proportions to each other. Creaming alone is indicated by a lessened amount of fat, but a normal amount of everything else, except total solids. Creaming and watering may be known by a general lowering of all constituents, but the deficiency in fat will be most marked.

Sub-Section VI.—Effects of Bad Milk.

Professor Mosler[2] has directed attention to the poisonous effects of "blue milk"[3]—that is to say, milk covered with a layer of blue substance,

[1] Mr. Bottle, Pharmaceutical Journal, February, 1873.

[2] Virchow's Archiv, Band xliii., p. 161 (1868).

[3] Blue milk is given by feeding cows with some vegetable substances, as *Myosotis palustris, Polygonum aviculare* and *Fagopyrum, Mercurialis perennis,* and other plants (Mosler); but this is different from the blue color referred to above.

which is in fact a *fungus*, either *Oidium lactis* or *Penicillium*, which seems to have the power, in certain conditions, of causing the appearance in the milk of an aniline-like substance.[1] The existence of this form of *fungus* was noted by Fuchs as long ago as 1861. Milk of this kind gives rise to gastric irritation (first noted by Steinhof); and, in four cases mentioned by Mosler, it produced severe febrile gastritis.

Milk which is not blue, but which contains large quantities of *Oidium*, appears, from Hessling's observations,[2] to produce many dyspeptic symptoms, and even cholera-like attacks, as well as possibly to give rise to some aphthous affections of the mouth in children.

Milk contaminated with pus from an inflamed udder, or an abscess on the udder, will give rise to stomatitis in children, and to aphthæ on the mucous membrane of the lips and gums.[3]

There has been much discussion whether the milk from foot-and-mouth disease in cows (*Eczema epizootica*) can cause affections of the mouth, or give rise in human beings to any disease similar to that of cattle. Pigs can certainly get the disease from the milk of the cow; sheep and hares, which also have the disease, perhaps get it from the saliva on herbage. In men the evidence is discordant, and in a great measure negative;[4] still there are some striking cases, which seem sufficient to prove that disease of the mouth (aphthous ulceration, general redness, diphtheritic-like coating, swollen tongue), and sometimes, though rarely, an affection of the feet may occur.[5] Some positive evidence has been adduced by Professor M'Bride,[6] Gooding,[7] Hislop,[8] Latham,[9] and Briscoe.[10] It is, of course, possible that some pus or blood from abscesses on the teat or udder may have got into the milk, but it is unlikely that this should have been overlooked.

A remarkable outbreak, which took place in Aberdeen, in April, 1881, has been recorded by Dr. Beveridge. The symptoms were febrile, but anomalous, and their cause is as yet unexplained. The cases were limited to the area of a particular milk supply, 88 per cent. of the families using the milk being attacked.[11] There seems reason to believe that bovine tuberculosis may be communicated to man through milk.[12]

A peculiar disease has several times prevailed in the Western States of

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[1] Erdmann (Journal für Prakt. Chem., xcix., p. 385, quoted by Mosler) has discovered that *vibriones* have the power of producing aniline coloring matter from protein substances.

[2] Virchow's Archiv, Band xxxv., p. 561. See also Report on Hygiene, Army Medical Reports, vol. vi., p. 385.

[3] See a good case by Dr. Fagan (British Med. Journal, November 13, 1869).

[4] See Dr. Thorne's paper in the Report of the Medical Officer to the Privy Council, p 294, and Mr. Simon's remarks on it, p. 62. Also Report on Hygiene, Army Med. Blue Book, vol. x., p. 223. Dr. Lawson Tait's negative evidence against it is exceedingly strong (Medical Times and Gazette, October, 1869); the disease was all round, and the milk was used, yet not a case occurred which could be referred to it. See also Whitmore's evidence in Marylebone (British Medical Journal, October, 1869).

[5] A case of the foot being involved is recorded by Mr. Amyot (Med. Times and Gazette, November 4, 1871).

[6] Brit. Med. Journal, November 13, 1869. An anonymous writer in the same journal, September, 1869, adduces also a few doubtful cases (p. 327), though his evidence is otherwise negative.

[7] Medical Times and Gazette, January, 1872.

[8] Edin. Med. Journal, November, 1869.

[9] British Medical Journal, May, 1872.

[10] Ibid., October, 1872.

[11] Sanitary Record, vol. ii., new series, p. 425.

[12] On Bovine Tuberculosis in Man, Creighton.

America, which is caused by the unboiled (not by the boiled) milk of cows affected with the "trembles," which is supposed to be produced by the cows feeding on *Rhus Toxicodendron.* In children who get this milk-sickness there is extreme weakness, vomiting, fall in bodily temperature, swollen and dry tongue, and constipation. Boiling appears to remove the hurtful qualities of the milk.[1] Cases of severe diarrhœa have occurred from the use of milk from goats that had fed on *Euphorbium;* this has been observed at Malta.

Milk may also be a means of conveying the poisons of enteric fever, of scarlet fever, and of diphtheria. In the first, it has probably usually arisen from the watering of the milk with foul water containing the agent, but it may possibly have in some cases arisen from the typhoid effluvia being absorbed by the milk, as in the case at Leeds. The scarlet fever and diphtheria poisons have probably got into the milk from the cuticle or throat discharges of persons affected with those diseases, who were employed in the dairy while ill or convalescent. Mr. Ernest Hart[2] has collected and tabulated 50 epidemics of enteric fever, 15 of scarlet fever, and 7 of diphtheria, which have been traced to milk poisoning.

SECTION XII.

BUTTER.

As an article of diet, butter supplies to most people the largest amount of fat which they take. Many persons take from 1½ to 2 oz. daily, if the butter used in cooking be included, and the average amount for persons in easy circumstances is 1 oz. daily. Butter appears to be easily digested by most persons, except when it is becoming rancid. It then causes dyspepsia and diarrhœa, and as a rule it may be said that decomposing fats of all kinds disagree.

Composition and Examination.

1. The average amount of water varies from 5 to 10 per cent., but may be higher, even in genuine butter. Hassall has found as much as 15½ per cent. in fresh, and 28½ per cent. in salt butter; Wanklyn records 23.6 per cent. in fresh butter supplied to Paddington Workhouse. The retail dealer, by beating up the butter in water, endeavors to increase the amount. This can be detected by evaporation in a water bath; if the quantity of water be very large, melting the butter will show a little water below the oil. An unusually small amount of water is suspicious (Angell), as suggestive of the presence of foreign fat.

2. *Casein.*—All butter contains some casein, as some milk is taken up with the cream. The best butter contains least. The amount can be told roughly by melting in a test-tube. The casein collecting at the bottom does not exceed one-third of the height of the contents of the tube in the best butter, or between one-third and one-half in fair butter. In bad butter it may reach to more than this. A better plan is dissolving the

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[1] Boston Med. and Surg. Journal, January, 1868, and Transactions of the Kentucky State Medical Society, quoted in Medical Times and Gazette. There have been many instances in the last half century, and they have all been collected by Hirsch.

[2] Transactions of the International Medical Congress, 1881, vol. iv., p. 391.

fat by ether, washing and then weighing the remainder; the casein then weighs from 5 to 3 grains in every 100 of very good butter. In bad butter it is much more than this.

The rancidity of butter is chiefly owing to changes in the fat, produced apparently by alterations in the casein, and therefore the greater amount of casein the more the chance of rancidity.

3. *Fat.*—The fat amounts to from 86 to 92 per cent. of the butter. Butter oil consists of volatile fatty acids (butyric, caproic, caprylic, and capric), and of non-volatile acids (stearic, palmitic, and oleic), all combined with glycerin. In examining it, the butter should be melted in a beaker-glass placed in hot water, and the fat should be poured off the casein, and allowed to cool. It then forms a solid and usually yellow mass, with the characteristic smell of butter, and should be further examined as follows:

(*a*) *Smell, taste, and color of this recongealed fat.*—The smell and taste are very characteristic, and with a little care the quality of butter, and even the presence of some adulterations, such as mutton fat, can be determined. The color is usually yellowish-white; other fats are white, but annatto may be used for coloring them, or true butter may be white, so that the coloration is not a safe test.

(*b*) *Examine the recongealed fat with the microscope.*—Butter shows nothing but oil-globules; lard and other fats often, but not always, contain acicular and stellate crystals of margaric (really a mixture of palmitic and oleic) and stearic acids, as pointed out by Hassall. Starch and other impurities may be sometimes seen, and tinged by iodine. The casein left after the fat has been poured off should be also examined, and starch, membrane, or other impurities may be seen in it. The polariscope may be used to bring out more strongly the stellate stearic acid crystals, if present. Angell and Hehner point out that even genuine butter sometimes shows crystals after melting and recongealing; they therefore think the presence of crystals ground for apprehension only, showing no more than that the fat has been melted.

(*c*) *Determine the melting-point of the fat after separation from the casein.*—Some of the fat should be put into a wide tube, and placed in an evaporating dish with water; a thermometer should be in the water and another in the fat. Raise the temperature of the water very gradually; remove the lamp from time to time, so that the temperature of the fat may rise slowly. Note the temperature when it begins to melt; when it is completely melted; and when (after removal from the warm water) it begins to recongeal, and becomes quite solid. The melting-points are, however, not constant, owing to the variable amounts of stearin and olein, and the volatile fatty acids, but still they run within tolerably narrow limits.

The temperature when the fat is completely melted appeared to be the most marked point in Dr. Parkes' experiments. The butter oil is most easily melted, and requires the greatest amount of cooling before recongealing; usually there is a difference, often 12° to 15°, between the points of commencing and completed fusion. The determination of the melting-point is, however, certainly more useful in proving that the butter has only slight admixture, than in proving complete purity, *i.e.*, the presence of a small quantity of lard or beef dripping would not raise the melting-point sufficiently for detection. In the case of beef dripping, also, the melting-point is rather close to that of butter.

Temperature[1] *of Melting and Solidifying.*

	Fusion.		Solidification.	
	Commencing.	Completed.	Commencing.	Completed.
	Degrees.	Degrees.	Degrees.	Degrees.
Butter oil	65–68	80–90	70–80	60–82[2]
Lard	76–80	100–115	90–100	71–75
Beef dripping	68–85	100–120	90–100	72–76
Mutton dripping	86–100	140–150	120–130	86–92
Palm oil[3]	81–92	110	88	69

(*d*) Angell and Hehner[4] recommend examining the sinking-point, by means of a little glass bulb weighted with mercury to 3.4 grammes; the mean sinking-point of 24 genuine butters was 35.5° C. (96° Fahr.), ranging from 34.3° C. to 36.3° C. (93.7° Fahr. to 97.3° Fahr.). The butter is melted and poured into a test-tube, and allowed to cool; as it cools a slight conical depression appears on the surface; this must be rendered even by remelting the upper part. If other fats are present, the depression is much more marked. The tube, with the bulb on the top of the fat, is then plunged into a larger beaker of water, which is gradually heated until the bulb sinks, the temperature of sinking being noted by means of a thermometer placed in the water.[5]

(*e*) Another method, recommended by the same chemists, consists in determining the percentage of fixed fatty acids, which seems to be pretty constant in butter fat, forming about 87.3 per cent. of its weight; 88.5 being adopted as a maximum, whereas most other fats give about 95.5 per cent.—the difference in butter being made up by volatile fatty acids. The plan employed is to saponify the fat by boiling with caustic potash and water, to decompose the soap with hydrochloric acid, filter and wash with boiling water, and then weigh the fatty acids remaining undissolved on the filter. The saponification is much facilitated by commencing the process with methylated spirit, as suggested by Mr. G. Turner.

(*f*) The specific gravity of butter fats has also been suggested by Mr. Bell as a good means of determining purity. He melts the fat at 100° Fahr., and weighs in a specific gravity bottle. He shows that the specific gravity of ordinary fats varies between 902.83 and 904.56; whilst that of butter fat rarely falls below 910, generally ranging between 911 and 913.[6]

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[1] Dr. Parkes attached more importance to the melting-point than to the solution in ether.

[2] It is rare for butter oil to be completely solid at 82°, but Dr. Parkes once found it so in an undoubtedly pure butter, made during the winter on a gentleman's private farm. But usually butter is not solid till 68° or 65°.

[3] Dr. Campbell Brown of Liverpool.

[4] Butter: its Analysis and Adulterations, 2d ed., 1877.

[5] Hassall employs a converse plan, using a float instead of a sinker, the temperature at which it rises to the surface being noted; this generally occurs about 2° C., or 5.6° Fahr. lower than the sinking-point above mentioned. Other plans have been proposed by Dr. Tripe, Mr. Heisch, Dr. Redwood, and Mr. Bell. Mr. P. Duffy has pointed out the curious fact that pork, mutton, and beef fats have two or three allotropic conditions, with different melting-points.

[6] Pharmaceutical Journal, July 22, 1876.

4. Salt is added to all butter. In fresh butter it should not be more than .5 to 2 per cent. (8 grains per ounce); in salt butter, not more than 8 per cent. (35 grains per ounce). To determine the salt, wash a weighed portion of butter thoroughly with cold distilled water, and determine the chloride of sodium by standard nitrate of silver. Dr. Tidy recommends incineration and weighing the residue; he places the limit at 7 per cent.

By this method the amount of water, casein, oil, and salt will be determined, and the quality of the butter oil will have been examined.

Scheme for a Short Examination.

1. Determine quality by the taste and smell of the whole butter, and of the melted, poured off, and recongealed fat.[1]

2. When melting for the fat in a tube, notice approximate amount of casein.

3. Determine the sinking-point by Angell's plan, or the floating-point by Hassall's.

4. Examine butter and recongealed fat with microscope, and add a weak solution of iodine to test for starch.

5. If time and means allow, determine the percentage of fixed fatty acids in the butter fat, by Angell and Hehner's method, or

6. Determine the specific gravity by Bell's method.

Adulterations.

Butter is supposed to be frequently adulterated with lard, and with beef, mutton, and horse fat, and with vegetable oils. In a process devised by Mége-Mouriès,[2] fresh beef suet is converted into a kind of butter (oleomargarine). But it is so complicated that it would not pay a dishonest tradesman to do it, and it could only be practised on a large scale.

A similar substance from New York has lately made its appearance in the market under the name of Butterine; it appears to be a wholesome fat, and as long as it is sold honestly as a substitute for butter, but not as genuine butter, its introduction will probably be a boon to many on account of its cheapness. The sinking-point and the determination of the amount of fixed fatty acids would probably detect it when sold for genuine butter.

Potato or other starches are sometimes added. It is a rare adulteration, and is at once detected by iodine, either at once or after melting. Gypsum and sulphate of barium have been added, it is said; this must be very rare, and be at once detected by melting and pouring everything off the insoluble powder, or by incinerating. Annatto is frequently used to color butter.[3]

Preservation of Butter.—Pouring water which has been boiled over butter will keep it for some time; but a better plan is one discovered by M. Brèon,[4] viz., water acidulated slightly (3 grammes to 1 litre) with acetic or tartaric acid, is added, and the whole is placed in a close-fitting vessel. Sugar also has a preservative effect, especially when mixed with a little salt.

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[1] Butter becomes rank and bad, by the cream being allowed to become sour before churning in consequence of dirty vessels; it is a good plan to stir up the cream from time to time.

[2] Pharmaceutical Journal, October, 1872.

[3] Angell and Hehner record two cases of adulteration by mixing with milk.

[4] Payen, Des Subst. Alim., 4th ed., p. 179.

SECTION XIII.

CHEESE.

As an Article of Diet.—It contains a very large amount of nitrogenous matter in small bulk (p. 212), and as it is agreeable to the palate, it must be an excellent food for soldiers in war. About ½ ℔ contains as much nitrogenous substance as 1 ℔ of meat and ⅓ of a ℔ as much fat. It does not, however, keep well in warm climates.

The quality is known by the taste. The only adulteration is from substances to give weight. Starch is chiefly employed, and can be detected at once by iodine. There is usually about 5 or 6 per cent. of salt.

Sulphate of copper and arsenious acid are sometimes used to destroy insects; the rind is then the most poisonous part. Copper is detected by ammonia or potassium ferrocyanide. Arsenic by any test (Reinsch's or Marsh's). Sometimes cheese becomes sour, particularly if made from sheep's milk, and may cause diarrhœa.

Acarus domesticus, *Aspergillus glaucus* (blue and green mould), and *Sporendonema casei* (red mould), form during decay. During decay the fat augments at the expense of the casein; leucin is produced, and valerianic and butyric acids. Lactic acid is also often produced, from the lactin of the milk contained in the cheese. The aroma of cheese partly arises from this decomposition, and the production of volatile acids.

SECTION XIV.

EGGS.

Composition and Choice.—An egg weighs from 600 to 950 grains, or even more; the average weight is about 2 ounces avoir.; 10 parts are shell, 60 white, and 30 yolk; the white contains 86 per cent. of water; the yolk 52 per cent.; 100 grains of egg, therefore, contain—

10	grains	shell.
22.8	"	albumen and fat.
67.2	"	water.
100.0		

If an egg weighs two ounces, it contains nearly 200 grains of solids; this is a convenient number to remember, as 100 grains correspond to 1 ounce.

For choice, look through the egg; fresh eggs are more transparent in the centre, old ones at the top. Dissolve 1 ounce of salt in 10 ounces of water; good eggs sink; indifferent swim. Bad eggs will float even in pure water.

Preservation.—Eggs are packed in sawdust or salt, or are covered with gum, butter, or oil, or placed in lime-water, with a little cream of tartar.[1] Boiling for half a minute also keeps them for some time; in fact, anything which excludes air.

The lime-water gives them, it is said, a peculiar taste, and makes the albumen more fluid.

[1] It is said that covering them with a solution of bees-wax in warm olive oil (⅓ of bees-wax, ⅔ds of olive oil) will keep them for two years.—Chemical News, August, 1865, p. 84.

SECTION XV.

CONCENTRATED AND PRESERVED FOOD.[1]

For the military surgeon this subject is so important, that it is desirable to put the chief facts under a separate section.

It is obvious how important it must be in time of war to have a food which may be at once nutritious, portable, easily cooked, and not liable to deterioration. Lind's sagacious mind long ago saw this, and he strongly urged the advisability of having on board ship prepared food of this kind. It must be remembered, however, that a man must get his 260 to 300, or even 350 grains of nitrogen, and 8 to 12 ounces of carbon, in each twenty-four hours, besides some hydrogen and salts. The work of the body when in activity cannot be carried on with less; and at present these elements cannot be presented to us in a digestible form in a smaller bulk than 22 or 23 water-free ounces. Concentration at present cannot be carried beyond this, and practically has not really been carried to this point. Life, however, and vigor may for some days be preserved with a much less amount; and the total amount of food has been reduced to 11 water-free ounces daily, with full retention of strength for seven days, though the body was constantly losing weight. For expeditions of three or four days, if transport were a matter of great difficulty, soldiers might be kept on 10 or 12 ounces of water-free food daily, provided they had been fully fed beforehand, and subsequently had time and food to make up the tissues of their own body, which would be expended in the time, and would not have been replaced by the insufficient food.

When we inquire into the concentrated foods now in the market, some of which profess to supply all the substances necessary for nutrition, we find them not very satisfactory. They are often not so concentrated as they might be, or are deficient in important principles, or are disagreeable to the taste.

Dried Meat.—Meat dried at a very low heat. It has lost the greater part of its water, is hard, and requires very careful cooking, but is believed to be nutritious when well prepared.

Messrs. M'Call of London have prepared an excellent dry meat; it is sold in packets, each of which weighs 4 oz., and is intended for one meal. It contains salt and pepper, and 12 per cent. of water.

Hassall's Flour of Meat.—Good fresh meat, freed from visible fat, is carefully dried at a very low temperature, and is pulverized by machinery, so that a very fine smooth powder is formed. This is mixed with about 8 per cent. of arrowroot, $2\frac{1}{2}$ per cent. of sugar, and 3 per cent. of a mixture of salts, pepper, spices, and coloring matter. The object of the arrowroot is to assist its suspension in water. When to this substance bread and a fair amount of fatty and vegetable foods is added, it seems to answer well. It keeps very well; but if the open tins are exposed to the air, after several months, it slightly changes color, and then acquires a peculiar odor. Subsequently it decomposes. But if well fastened, it will keep for a very long time. Dr. C. A. Meinert[2] has also brought out a flour or powder of meat (Fleischpulver), which is well spoken of.

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[1] Dr. Letheby stated that from 1800 to 1855 there were 177 patents taken out for drying and preserving food. Of these 26 were for drying the food, 31 for excluding atmospheric air, and 8 for giving an impervious coating.

[2] Armee- und Volks-Ernährung, von Dr. C. A. Meinert, Berlin, 1880. This work contains a great amount of information on the subject of food, as well as extensive tables of analyses.

Under the terms *Tasajos* and *Charqui*, two kinds of meat are prepared in South America; it is probable that these terms have not always been used in the same sense. According to Mr. Bridges Adams, Tasajos is meat cut in thin slices, dipped in brine, and then partially dried. Charqui is thin strips of muscular fibre from which the fat is removed, dried rapidly by sun heat, and sprinkled with maize.

The dried meat of the Kaffirs (beltong) is very much the same; great hunks of beef are sun-dried, and remain undecomposed for a long time. So also in Egypt the meat is dried by exposure to the sun and north wind.

The Pemmican of the Artic voyagers is a mixture of the best beef and fat dried together, and is an excellent food, though rather expensive. Sugar is sometimes added, and sometimes raisins and currants; the latter would be a very desirable addition where there was a deficiency of vegetable food.

Liebig's *Extractum Carnis* is the juice of meat extracted on the following plan:—Every particle of meat is separated from fat and tendons, and is then subjected for some time to a moderate heat; a viscid dark extract at last collects, which contains the salts, creatin, and other organic nitrogenous substances. Mixed with warm water, this extract gives a highly agreeable and nutritious beef-tea or mutton broth. One ℔ of mutton gives about two fifths of an ounce of extract. It has the remarkable quality of not decomposing; Liebig had some for fifteen years in a bottle loosely stoppered.

There are now numerous samples of *Extractum Carnis* in the market, prepared in South America and Australia. The majority have an almost identical composition.

When Liebig's extract is taken during fatigue, it is found to be remarkably restorative, increasing the power of the heart, and removing the sense of fatigue following great exertion. Mixed with wine, it has been employed with great success in rousing men in collapse from wounds. As, however, the nitrogenous compounds in the *Extractum* are not in the form of albumen or fibrin, but of other compounds (creatin, extractives soluble in water and alcohol), it has been supposed that the nitrogen is not capable of being employed in the nutrition of muscles or gland-cells, and, in fact, that the *Extractum Carnis* does not represent a true nutritive albuminate. Liebig considered it to be a condiment which increases the power of the stomach to digest vegetable food; and Hörschelmann,[1] who does not consider it a substitute for meat, yet thinks that it aids in digesting hard meat, and that the meat ration can be lessened when it is used. By some its action has been compared to that of tea and coffee, but there does not appear to be any close parallel.

When taken in very large doses, the extract (like large quantities of meat) does sometimes cause heaviness and torpor, and this has been ascribed to the potash salts, but it may be a question whether it is not owing to the excess of the nitrogenous extractive matter.

About 230 grains of extract in one pint of water are nearly equal to a pint of beef-tea made from $\frac{7}{10}$ths ℔ of fresh beef; $\frac{3}{4}$ths ounce of extract in one pint are equal to a pint made from 1 ℔ of fresh beef. There is, however, a general opinion that the extract beef-tea is not so good as that made at once from fresh beef; a mixture of the two is well spoken of.

The "concentrated beef-tea" is beef-tea and the juices of the compressed

[1] Schmidt's Jahrb., January, 1872, p. 21.

beef mixed and evaporated. This is a highly nutritious substance, and most useful to the army surgeon. Mixed with wine, and given as soon as possible after wounds are received, in the time of shock and collapse, it was found in the Austrian army (in 1859) to save the lives of many wounded men, and the experience of the Federal American Army was to the same effect (Hammond). *Extractum Carnis* is now made also by pressure without heat.

Johnston's Fluid Beef contains a large proportion of the fibrin of meat, in addition to the juices. It appears to be a good preparation.

Extract of Mutton.—An Australian extract of mutton is now sold, which is more solid than Liebig's extract, and differs from it in containing much fat. It is a very good preparation.

Bellat's Extract of Meat.[1]—This contains the juice of cooked vegetables in addition to that of meat. A little less than an ounce (25 grammes) in $1\frac{3}{4}$ pint (1 litre) of water makes a good beef-tea.

Edward's patent desiccated Soup consists of a mixture of beef and vegetables; is easily prepared by boiling in water, about an ounce to a pint of water; it was well spoken of in the Ashantee war.

Meat Biscuits.—These biscuits or powders, for they are generally powdered and sold in canisters, are formed by mixing rich extract of meat with wheat flour, and drying. They were very much used in the American war. In some cases the meat is so much dried as to be quite indigestible.

Meat biscuits can be made in a very simple way, by mixing together, cooking, and baking 1 ℔ flour, 1 ℔ meat, $\frac{1}{4}$ ℔ fat (suet), $\frac{1}{2}$ ℔ potatoes, with a little sugar, onion, salt, pepper, and spices. A palatable meat biscuit, weighing about $1\frac{1}{4}$ ℔, containing 10 to 12 per cent. of water, is then obtained, which keeps quite unchanged for four months.

Pea Sausage.—In the Franco-German war the Germans made great use of a pea sausage, made by mixing pea-flour and fat pork, with a little salt. It is ready cooked, but can be made into a soup. It was much relished for a few days, but the men got eventually tired of it, and in some it produced flatulence and diarrhœa.

Flour Sausages.—A mixture of pork and wheat flour has been used in the same way.

Maize and Beef.—The Germans in 1870 made also use of mixture of maize and beef, which appears to have been much liked.

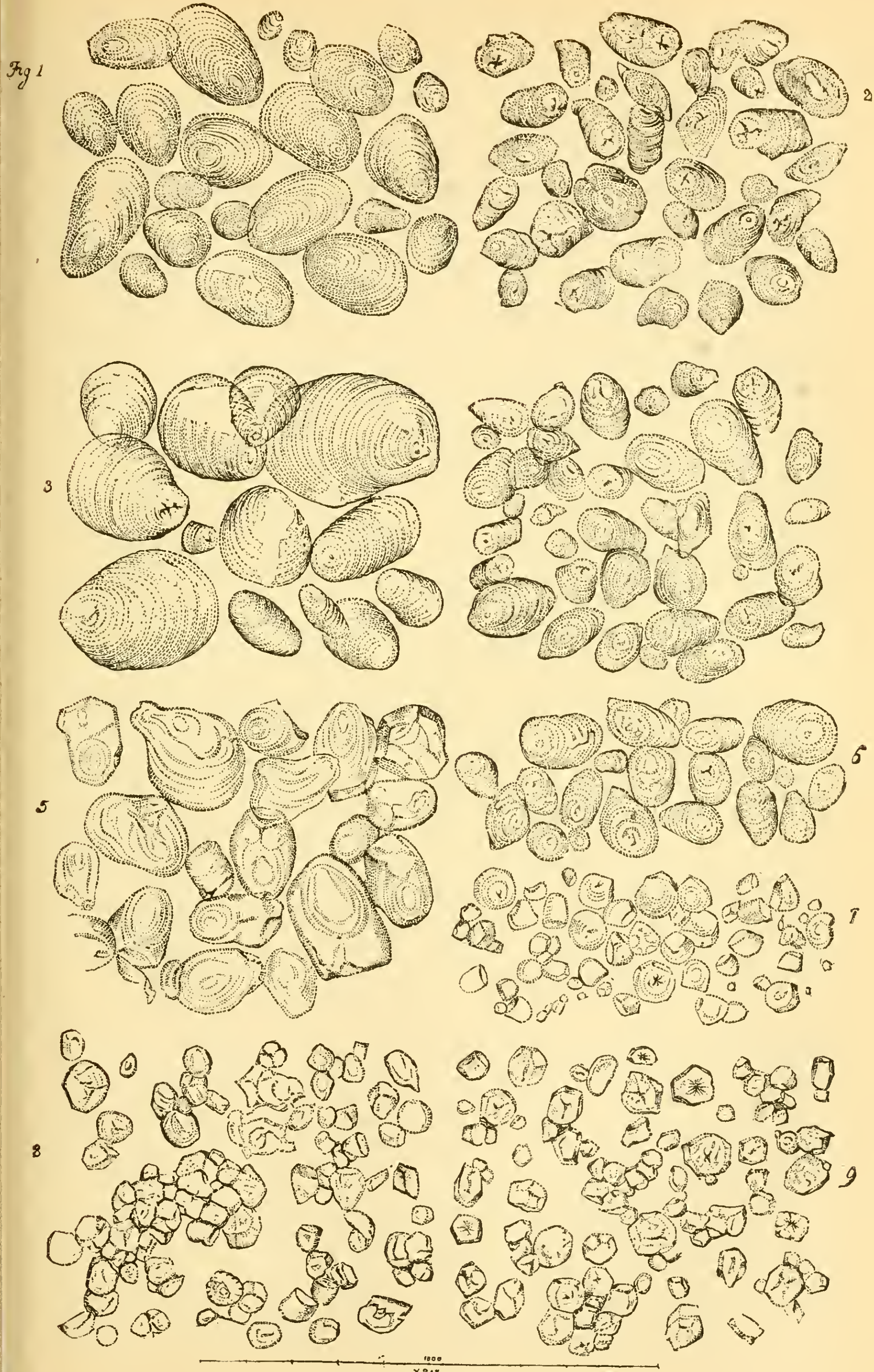
Dried Cerealia.—Many flours, if well dried, will keep for a long time. There are now in the market different kinds of malt biscuit and granulated malt food. Liebig's food for infants is composed of equal parts of wheaten flour and malt flour mixed with a little potassium carbonate and cooked with 10 parts of milk. The wheat and malt flour are usually cooked, and sold in powder ready to be boiled with the milk.

Dried Bread.—In addition to biscuit already described, bread has been partially dried by being pressed in an hydraulic press (method of Laignel). Much water flows out, but when taken out the bread still feels moist. In a day or two, however, it becomes as hard as a stone, and in a year's time will be found good and agreeable. Placed in water, it slowly swells. The "pain biscuité" of the French army is bread dried by heat.

Dried Potatoes are sold in two forms—slices and granulated. In either case the potato is easily cooked, and is very palatable. It should be soaked in cold water first for some time, then slowly boiled, or, what is much better, steamed. The directions for cooking Edward's preserved potato (which is

[1] Poggiale, Rec. de Mem. de Mil. Milit., Avril, 1868, p. 268.

Plate VII.



1. Potato Starch.
2. Bermuda Arrowroot.
3. Tous les Mois.
4. St. Vincent Arrowroot.
5. Sago of Commerce.
6. Port Natal Arrowroot.
7. Rio Arrowroot.
8. Tapioca.
9. Maize.

granulated) are: "To three-quarters of a pound add about one quart of boiling water, stirring it at the same time; cover it closely; the basin or vessel used should be kept hot; let it stand for ten minutes; then well mash, adding butter, salt, etc., at discretion." It is stated to be equal to six times its bulk of the fresh vegetable, but this is hardly borne out by analysis; four times is as high as it would be safe to allow. The analyses made by Professor Attfield and Dr. de Chaumont[1] show that a ℔ of preserved potato contains the solid matter of only 3½ ℔ of ordinary fresh potatoes.

Dried Vegetables (*other than Potatoes*).—Dried and compressed vegetables of all kinds (peas, cauliflowers, carrots, etc.) are now prepared, especially by Messrs. Masson & Challot, so perfectly that, if properly cooked, they furnish a dish almost equal to fresh vegetables. Professor Attfield found that dried compressed cabbage contained the solids of *seven* times its weight of fresh cabbage, whilst the mixed vegetables contained *five and a half* times the solids of the fresh vegetables. They must be cooked very slowly. If there is any disagreeable taste from commencing putrefaction, which is very rare, a little chloride of lime removes it at once. Potassium permanganate can be also used for this purpose.

As anti-scorbutics they are said to be inferior to the fresh vegetable (experience of American war), but are still much better than nothing.[2]

Preserved Vegetables, that is, vegetables preserved in their natural condition (cooked), are much to be preferred, both as being more palatable and as being more nutritious and better anti-scorbutics. They occupy, however, much greater bulk.

Dried Milk.—Preserved milk is sold in a liquid form, but is also sold as a powder, which is very well prepared.

Concentrated Milk.—Milk is evaporated at low steam heat to the consistence of a thick syrup, and white sugar is added. After opening the tins the samples remain good for over a month.

Dried Eggs.—The yolk is not easily kept after drying, but the white can be so; it is cut into thin scales, and forty-four eggs make about 1 ℔. The yolk and white are also mixed with flour, ground rice, etc., and are then dried.

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[1] Report of Committee on Scurvy, 1877.

[2] Professor Attfield (loc. cit.) considers that in the compressed vegetables some, at least, of the juice is lost in the preparation, probably by pressure.

CHAPTER VII.

BEVERAGES AND CONDIMENTS.

SECTION I.

ALCOHOLIC BEVERAGES.

Although it is convenient to place all the beverages which contain Alcohol under one heading, they yet differ materially in composition and effects.

Sub-Section I.—Beer.

Composition.—The law formerly allowed only malt and hops to be used in brewing,[1] but sugar (under the name of *saccharum*) is now largely substituted, as well as bitter substances other than hops.

The specific gravity varies from 1006 to 1030, or even more, in the thick German beers; the average in English beers and porters is from 1010 to 1014. The percentage of extract (dextrin, cellulose, sugar, lupulite, and hop resin) is from 4 to 15 per cent. in ale, and from 4 to 9 per cent. in porter. It is least in the bitter, and highest in the sweet ales. The alcohol varies from 1 to 10 per cent. in volume. The free acidity which arises from lactic, acetic, gallic, and malic acids, ranges (if reckoned as glacial acetic acid) from 18 to 45 grains per pint. The sugar has a great tendency to form so-called glucinic (or glucic) acid ($C_{12}H_{11}O_9$). There is a small quantity of albuminous matter in most beers, but not averaging more than .5 per cent. The salts average .1 to .2 per cent., and consist of alkaline chlorides and phosphates, and some earthy phosphates. There is a small amount of ammoniacal salt. The dark beers, or porters, contain caramel and assamar. Free carbon dioxide is always more or less present; the average is .1 to .2 parts by weight per cent., or about 1¾ cubic inch per ounce. Volatile and essential oils are also present.

Adopting mean numbers, 1 pint (20 ounces) of beer will contain:—

Alcohol	1 ounce.
Extractives, dextrin, sugar	1.2 " (524 grains).
Free acid	25 grains.
Salts	13 grains.

[1] In the Licensing Act (1872), clause 19 contains penalties for using any deleterious substance for mixing with liquors sold by persons having licenses under the Act, and in the first schedule to the Act is a list of deleterious ingredients, viz.: "Cocculus indicus, chloride of sodium (otherwise common salt), copperas, opium, Indian hemp, strychnine, tobacco, darnel seed, extract of logwood, salts of zinc or lead, alum, and any other extract or compound of any of the above ingredients." Several articles, which are supposed to be used as adulterants, are omitted from this list.

Physiological Action.—The action on tissue metamorphosis, so far as is known, is supposed to be one of lessened excretion ; the urea and pulmonary carbon dioxide being both decreased. If this be the case, it is not owing to the alcohol, at least in moderate dietetic doses, but to some of the other ingredients ; but the experiments require repetition.[1] On the nervous system the action is probably the same as that of alcohol. The peculiar exhausting or depressing action of beer taken in large amount has been ascribed by Ranke [2] to the large amount of potash salts, but probably the other constituents (especially the hop) are also concerned.

When beer is taken in daily excess, it produces gradually a state of fulness and plethora of the system, which probably arises from a continual, though slight interference with elimination, both of fat and nitrogenous tissues. When this reaches a certain point, appetite lessens, and the formative power of the body is impaired. The imperfect oxidation leads to excess of partially oxidized products, such as oxalic and uric acids. Hence many of the anomalous affections, classed as gouty and bilious disorders, which are evidently connected with defects in the regressive metamorphosis.

The question, What is excess? is not easy to answer, and will depend both on the composition of the beer, and on the habits of life of those who take it; but judging from the amount of alcohol which is allowable, from one pint to two pints, according to the strength of the beer, is a sufficient amount for a healthy man.

Examination of Beer.

This is directed to ascertain—1. Quality ; 2. Adulterations.

1. quality.

Physical Characters.—The beer should be transparent, not turbid. Turbidity arises from imperfect brewing or clarifying, or from commencing changes. If the latter, the acidity will probably be found to be increased. The amount of carbon dioxide disengaged should neither be excessive nor deficient.

The taste should be pleasant. If bitter, the bitterness should not be persistent. It should not taste too acid.

Smell gives no indication till the changes have gone on to some extent.

If there is any turbidity, microscopic examination will detect the presence of abnormal organisms, as figured by Pasteur.[3]

2. *Determine Specific Gravity.* —If this is done after the alcohol is driven off, an approximate conclusion can be formed of the amount of solids by dividing by 4 the excess of the specific gravity over 1000. The more extract, the greater is the body of the beer.

3. *Determine Acidity.*—This is a very important matter, as the increase of acidity is an early effect when beer is undergoing changes.

The acidity of the beer consists of two kinds.

Volatile Acids, viz., acetic and carbonic.

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[1] Binz (Journal of Anatomy and Physiology, May, 1874) states that alcohol diminishes both the pulmonary carbonic acid and urea.

[2] Phys. des Menschen, 1868, p. 139.

[3] Études sur la Bière, 1876, plate i., p. 6.

Non-Volatile Acids, viz., lactic, gallic or tannic, malic, and sulphuric, if it has been added as an adulteration.

To determine the acidity of beer we must use an alkaline solution of known strength, 1 C.C. of which is equal to 6 milligrammes of glacial acetic acid ($C_2H_4O_2$), or to 9 milligrammes of lactic acid ($C_3H_6O_3$).[1]

Take 10 C.C. of the beer to be examined, and drop into it the alkaline solution from a burette, till exact neutrality (as tested by turmeric and litmus papers) is reached. Then read off the number of C.C. of alkaline solution used; multiply by 6, and the result will be the amount of total acidity in the quantity of beer operated on, expressed as milligrammes of glacial acetic acid (the symbols being always used in the report). By shifting the decimal point two places to the right, the amount per litre is given. To bring grammes per litre into grains per pint multiply by 70, and divide by 20; or, what is the same thing, multiply at once the number of C.C. of alkaline solution used by 5.25 (short factor).

The total acidity can be divided into fixed and volatile by evaporation. While the total acidity is being determined, evaporate another measured quantity of beer to one-third, make up the original bulk with distilled water, and determine the acidity. The acetic and carbonic acids being volatile, are driven off, and lactic and other acids remain. Deduct the amount of alkaline solution used in this second process from the total amount used, and this will give the amount used for the volatile and fixed acidities respectively; express one in terms of acetic, the other of lactic acid. Short factor for lactic acid = 7.875. The fixed acidity is greater than the volatile in almost all beers, and sometimes five or six times as much.

Example.—10 C.C. of beer took 5 C.C. of alkaline solution: $5 \times 5.25 = 26.45$ grains of glacial acetic acid per pint = total acidity.

After boiling and making up to original bulk with distilled water, 10 C.C. took 4 C.C. of alkaline solution: $4 \times 7.875 = 31.5$ grains of lactic acid per pint = fixed acidity. The difference between the amounts of alkaline solution used, $5 - 4 = 1$ multiplied by 5.25, gives the volatile acidity.

Generally speaking, the amount of total acidity of beer given in books is too great. It is seldom found to be more than 30 grains per pint, and even rarely reaches that; sometimes it is not more than 14 or 15 grains. In thirty-one kinds of porter and stout, the acidity per pint varied from 25.22 grains (the highest) to 14.14 grains (the lowest amount). In twenty-three kinds of ale, the highest and the lowest amounts per pint were 34.39 and 7.97 per grain.[2]

4. *Determine Amount of Alcohol.*—There are various ways of doing this, but one of the two following will be sufficient.

Measure a certain quantity, say one pint of beer, and take the specific gravity at 60° or 68° Fahr.[3] 1st. Put into a retort and distil at least two-thirds. Take the distillate, dilute to original volume with distilled water, determine the specific gravity at 60° or 68° by a proper instrument, and then refer to the annexed table of specific gravities—opposite the found specific gravity the percentage of alcohol is given in *volume* (not in *weight*).

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[1] See Appendix A, Vol. II.

[2] British Medical Journal, June, 1870.

[3] Hassall recommends previous removal of CO_2, by shaking up in a corked bottle for ten minutes, opening the bottle from time to time, and sucking air through it with a tube. This is more necessary with bottled than draught beer.

2d. Then, to check this, a plan recommended by Mulder may be used. Take the residue of the beer in the retort, dilute with water to the original volume, and take the specific gravity at 60° or 68°.

Then deduct the specific gravity before the evaporation from the specific gravity after it, take the difference, and deduct this from 1000 (the specific gravity of water), and look in the table of specific gravities for the number thus obtained; opposite will be found the percentage of alcohol. The results of these two methods should be identical.

If there is no retort, this second plan may be used with a common evaporating dish, the alcohol being suffered to escape. A common urinometer (tested for correctness, in the first place, by immersion in distilled water at 62° Fahr.) may be employed for determining the specific gravity. The plan is very useful for medical officers; it requires nothing but a urinometer and evaporating dish, with reasonable care and slowness of evaporation, so as not to char the residue and render it insoluble.

Alcohol (Volume) according to Specific Gravity.

100 parts.		Specific Gravity.		100 parts.		Specific Gravity.	
Alcohol.	Water.	At 68°.	At 60°.	Alcohol.	Water.	At 68°.	At 60°.
50	50	0.914	0.917	24	76	0.966	0.968
49	51	0.917	0.920	23	77	0.968	0.970
48	52	0.919	0.922	22	78	0.970	0.972
47	53	0.921	0.924	21	79	0.971	0.973
46	54	0.923	0.926	20	80	0.973	0.974
45	55	0.925	0.928	19	81	0.974	0.975
44	56	0.927	0.930	18	82	0.976	0.977
43	57	0.930	0.933	17	83	0.977	0.978
42	58	0.932	0.935	16	84	0.978	0.979
41	59	0.934	0.937	15	85	0.980	0.981
40	60	0.936	0.939	14	86	0.981	0.982
39	61	0.938	0.941	13	87	0.983	0.984
38	62	0.940	0.943	12	88	0.985	0.986
37	63	0.942	0.945	11	89	0.986	0.987
36	64	0.944	0.947	10	90	0.987	0.988
35	65	0.946	0.949	9	91	0.988	0.989
34	66	0.948	0.951	8	92	0.989	0.990
33	67	0.950	0.953	7	93	0.990	0.991
32	68	0.952	0.955	6	94	0.992	0.992
31	69	0.954	0.957	5	95	0.994	0.994
30	70	0.956	0.958	4	96	0.995	0.995
29	71	0.957	0.960	3	97	0.997	0.997
28	72	0.959	0.962	2	98	0.998	0.998
27	73	0.961	0.963	1	99	0.999	0.999
26	74	0.963	0.965	0	100	1.000	1.000
25	75	0.965	0.967				

Alcohol is sometimes stated as *weight in volume.* The following table shows tolerably accurately the relation between the two, and the relative amount of proof-spirit, so that a little calculation will reduce one table

into another, if desired. In other words, if the percentage of alcohol in *volume* be multiplied by .8, the *weight* of the alcohol is given per cent. If the percentage of alcohol in *weight* is multiplied by 1.25, the *volume* is given. If the percentage *volume* of alcohol be multiplied by 1.76, the amount of *proof-spirit* is given.[1]

Per cent. in Volume.	Per cent. in Weight.	Proof-Spirit.	Per cent. in Volume.	Per cent. in Weight.	Proof-Spirit.
1	0.8	1.76	6	4.8	10.56
2	1.6	3.54	7	5.6	12.32
3	2.4	5.35	8	6.4	14.00
4	3.2	7.00	9	7.2	15.76
5	4.0	8.80	10	8.0	17.60

5. The *solids* can be determined by evaporation, and the *ash* obtained by incineration; but medical officers will seldom have occasion to do this. The specific gravity of the de-alcoholized beer gives a sufficient approximation.

6. Evaporate the beer to a syrupy consistence; it should have a pleasant bitter taste.

The points, then, to be determined in judging of quality are—1. Taste; 2. Appearance; 3. Microscopic characters; 4. Specific gravity of de-alcoholized beer, from which we find the per cent. of extract; 5. Acidity; 6. Amount of alcohol; 7. Taste of syrupy extract.

2. ADULTERATIONS OF BEER.[2]

1. *Water.*—Probably the most frequent adulteration; detected by taste; determining amount of alcohol and specific gravity of the beer free from alcohol.

2. *Alcohol.*—Seldom added; the quantity of alcohol is large in proportion to the amount of extract, as determined by the specific gravity after separation of the alcohol.

3. *Sodium* or *Calcium Carbonate in order to lessen Acidity.*—Neither adulteration can be detected without a chemical examination. Evaporate beer to a thick extract, then put in a retort, acidulate with sulphuric acid, and distil; if calcium or sodium acetate be present, acetic acid in large quantity will pass over. The extract always contains some acetate, but only in small quantity.

Lime.—Evaporate to dryness another portion of beer, incinerate, dissolve in weak acetic acid, and precipitate by ammonium oxalate. In unadulterated beer the precipitate is moderate only.

Excess of soda, for some always exists in beer, is detected with much greater difficulty, and it will be well not to attempt this. Mulder states that the presence of too great a quantity of lactates may be determined by boiling the beer with zinc carbonate, when lactate of zinc deposits.[3] In

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[1] For method of testing by Sykes' hydrometer, see Appendix, Vol. II.

[2] In his speech in the House of Lords (April 17, 1872, Times' report), Lord Kimberley stated that a common adulteration is as follows: A certain amount of beer is drawn from the cask of 84 gallons, and then 6 ℔ of "foots" (a black coarse sugar), 1½ gallon of "finings" (made from skins of soles and other fish), and 12 gallons of water are put in per cask. This beer is ready for sale in two hours, and must be drunk in two days or it goes bad. Salt and copperas are added by some, but the use of copperas is said not to be general. Ale and stout are not mixed with water, but "finings" are used.

[3] De la Bière (French edition), 1861, p. 258.

these cases the beer has begun to change, and the microscope and reference to Pasteur's plate will greatly assist.

4. *Sodium Chloride.*—This is hardly an adulteration, unless a very large quantity is added.[1] Take a measured quantity of the beer; evaporate to dryness; incinerate at as low a heat as possible; dissolve in water, and determine the chlorine by the standard solution of nitrate of silver.

5. *Ferrous Sulphate.*—If the beer be light-colored, a mixture of potassium ferricyanide and ferrocyanide (Faraday's test) may be added at once, and will give a precipitate of Prussian blue; if the beer be very dark-colored, it must be decolorized by adding solution of lead subacetate and filtering.

Or evaporate a portion of beer to dryness and incinerate; if any iron be present the ash is red; dissolve in weak nitric acid, and test with potassium ferrocyanide. Two grains of ferrous sulphate to nine gallons of water give a red ash (Hassall). The ash of genuine porter is always white, or grayish white (Hassall).

6. *Sulphuric acid* is added to clarify beer, and to give it the hard flavor of age. If the beer be pale, add a few drops of hydrochloric acid, and test with barium chloride. A *very dense* precipitate may show that sulphuric acid has been added, but it must be remembered that the water used in brewing may contain large quantities of sulphates. (The Burton spring water is rich in calcium sulphate.) If there be a *large* precipitate, then determine the acidity of the beer before and after evaporation; if the amount of fixed acid be found to be *very* large, there will be no doubt that sulphuric acid has been added; or precipitate with baryta, and weigh.

Mulder recommends that the extract of the beer be heated, and the sulphur dioxide which is disengaged led into chlorine water; sulphuric acid will be found in the chlorine water, and may be tested for as usual.

7. *Alum.*—Evaporate to dryness; incinerate, and proceed exactly as in the analysis of alum in BREAD. The substance added to give "head" to beer is a mixture of alum, salt, and ferrous sulphate.

8. *Burnt Sugar—Essentia bina—Foots.*—Evaporate the beer to an extract; dissolve in alcohol; evaporate again to extract, and taste. According to Pappenheim, these substances prevent the regressive metamorphosis of the tissues, and thus injure health. Burnt sugar is added to porter to give color, and the addition is not illegal.

9. *Capsicum—Peppers—Grains of Paradise.*—Evaporate to dryness carefully; dissolve in alcohol; filter; evaporate very carefully to dryness, and taste if there is any pungency. In fourteen out of twenty samples of illicit beer, Mr. Phillips found that grains of paradise had been added. It is said that the oils of pimento, zedoary, and ginger are sometimes used.

10. *Aloes.*—The taste alone is not reliable. Dr. Koehler[2] proposes to evaporate the beer. Dissolve the residue in nitric acid, when a yellowish-red liquid is obtained, which takes a deep blood-red color when treated with liq. potassæ and glucose, or with liq. potassæ and either cyanide of potassium or sulphide of ammonium, if aloe-resin is present. The nitric acid solution is not decolorized by stannous chloride; if hops only have been used, it is decolorized.

11. *Colocynth.*—The residue of evaporated beer, heated with nitric acid, yields a yellow solution; with concentrated sulphuric acid, an intense

[1] The Inland Revenue Office allows 50 grains of sodium chloride per gallon.
[2] Schmidt's Jahrb., 1871, No. 10, p. 22.

red solution; and a cherry-red color is given with Froehde's test (molybdate of sodium dissolved in sulphuric acid).[1]

12. *Colchicin.*—A case is recorded by Dr. Böttern[2] of Faaborg, in Norway, where colchicin was detected in some English beer, and caused symptoms of poisoning (vomiting, diarrhœa, burning pain in the head, stomach, etc.).

13. *Santonin.*—Evaporate beer to extract; treat with alcohol, filter, evaporate, and prepare the santonin as usual by boiling with lime, and precipitating by an acid.

14. *Cocculus indicus.*—It is not known whether much of this is now used. The witnesses examined in 1856 by the Committee of the House of Commons (Scholefield's) all doubted it; a large quantity of *Cocculus indicus* is, however, annually imported, and no other use is known.[3] In two instances out of twenty specimens of adulterated beer, analyzed in 1863 by Mr. Phillips, *Cocculus indicus* was found in large quantities.

For the detection of *Picrotoxine,* Herapath recommends that the beer be first treated with lead acetate; filtered; excess of lead got rid of by hydrogen sulphide; fluid evaporated to a small bulk, and mixed with animal charcoal. The charcoal absorbs the picrotoxine; it is boiled in alcohol, and the alcohol is evaporated on slips of glass. The picrotoxine crystallizes as plumose tufts of circular or oat-shaped crystals.

Dr. Langley, of Michigan,[4] recommends acidulating the beer with hydrochloric acid and agitating with ether; the ethereal solution yields on evaporation crystals of picrotoxine.

A plan devised by Depaire is considered by Koehler as one of the easiest and at the same time the best. Mix one litre of beer with finely powdered rock salt: resinous and extractive matters are thrown down. Shake the liquid with ether; an impure picrotoxine is obtained, which can be purified.

None of these processes will give more than $\frac{4}{10}$ths of the picrotoxine.

When the crystals of picrotoxine are obtained, test them as follows:—

(*a*) Rub the crystals with 3 or 4 parts of pure nitrate of potassium; add 1 or 2 drops of strong sulphuric acid, and then an excess of strong solution of soda or potash. A bright reddish-yellow color is given, if picrotoxine be present (Langley).

(*b*) Dissolve the crystals in strong sulphuric acid; a yellow fluid is obtained. Stir it with a glass rod which has been dipped in a concentrated solution of potassium bichromate; a bluish-violet color is obtained (like a strychnine reaction), which changes soon into brown, brown green, and at last apple green.

(*c*) If a good deal of picrotoxine is obtained, dissolve it in water, and put a small fish in the water; the poisonous effects occur in a short time.

15. *Strychnine* or *Nux Vomica.*—This is a very uncommon adulteration, if it ever occur. Add animal charcoal to the beer; digest for twenty-four hours; pour off the beer; boil the charcoal in alcohol; filter; evaporate one-half; add a few drops of liquor potassæ and then ether; agitate; pour off ether, and evaporate to dryness; test for strychnine by the color test (sulphuric acid and potassium bichromate, or peroxide of lead, or manganese, or potassium permanganate).[5]

16. *Tobacco* is occasionally used; in twenty specimens of illicit beer

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[1] Koehler, op. cit.

[2] Med. Times and Gazette, May 16, 1874, p. 29.

[3] It is said to be obtainable from wholesale druggists under the name of *multum*.

[4] Chemical News, September 6, 1862.

[5] Other vegetable bitters are used, but their detection is difficult and uncertain. Mr. Sorby recommends the spectroscope for detecting calumba root.

examined in 1863 by Mr. Phillips, of the Inland Revenue Department, tobacco was found in one.

17. *Picric (Trinitrophenic) Acid.*—Lassaigne recommends the addition of subacetate of lead and animal charcoal ; if the beer has still a yellow color, picric acid is present. But, as Mulder and Hassall observe, many beers destitute of picric acid remain yellow. Pohl advises to add white uncombed wool ; if picric acid be present, it stains it. This is an uncertain test. H. Brunner extracts the picric acid from the wool with hot aqueous ammonia ; concentrates to a small bulk, and tests with a drop of solution of cyanide of potassium. A red coloration of isopurpurate of potassium will be produced if there be 1 part of picric acid in 500,000 of water (Hassall).

18. *Copper.*—Evaporate a portion of the beer to dryness ; incinerate ; dissolve in weak nitric acid ; test for copper by the insertion of a clean knife ; by addition of ammonia and of potassium ferrocyanide.

19. *Lead.*—Evaporate a considerable quantity of the beer to dryness ; incinerate ; dissolve in weak nitric acid, and test for lead as usual.

SUB-SECTION II.—WINES.[1]

Composition.

The composition of wine is so various that it is difficult to give a summary. The following are the chief ingredients:—

1. *Alcohol.*—From 6 to 25 per cent., volume in volume, of anhydrous alcohol. It has been, however, stated that the fermentation of the grape, when properly done, cannot yield more than 17 per cent., and that any amount beyond this is added.[2] Some of the finest wines do not contain more than 6 to 10 per cent.

	Per cent. of Alcohol (Volume in volume).	
Port (*analyzed in England*)	16.62[3]	to 23.2
Sherry (*analyzed in England*)	16	" 25
Madeira (*analyzed in England*)	16.7	" 22
Marsala (*analyzed in England*)	15	" 25
Bordeaux wines, red (mean of 90 determinations of different sorts : Château Lafite, Margaux, Larose, St. Emilion, St. Estèphe, etc.)	6.85	" 13
Bordeaux wines, white (mean of 27 determinations of sorts : Sauternes, Barsac, Bergerac, etc.)	11	" 18.7
Rhone wines, red (Hermitage, Montpellier, Frontignan, etc.)	8.7	" 13.7

[1] For a full account of wines, see the work by Thudichum and Dupré (Origin, Nature, and Use of Wine, 1872).

[2] Mulder (On Wine, p. 186) quotes Guijal to the effect that pure port never contains more than 12.75 per c nt. of pure alcohol ; but Mulder doubts this. Dr. Gorman stated before the Parliamentary Committee that pure sherry never contains more than 12 per cent. of alcohol, and that 6 or 8 gallons of brandy are added to 108 gallons of sherry. Thudichum and Dupré (On Wine, p. 682) state that a natural wine may contain a minimum of 9, while the maximum limit is 16 per cent. (of weight in volume). They also state that a pipe of 115 gallons of port wine has never less than 3 gallons of brandy added to it, and the rich port wines have 13 to 15 gallons added. It would seem that the natural wines of Australia contain a larger quantity of alcohol in some instances than any European wine.

[3] Some port used in the Queen's establishment contained only 16.62, and the highest percentage was 18.8 (Hofmann). The sherry contained only 16 per cent. and the claret 6.85 to 7 per cent. The highest percentage found by Thudicum and Dupré in port wine was 19.2 per cent. of weight in volume = 23.4 per cent. volume in volume.

	Per cent. of Alcohol (Volume in volume).		
Roussillon	11	to	16
Burgundy, red (Beaune, Macon)	7.3	"	14.5
" white (Chablis, etc.)	8.9	"	12
Pyrenean	9	"	16
Champagnes	5.8	"	13
Moselles	8	"	13
Rhine wines (Johannisberger, Hochheimer, Rüdesheimer, etc.)	6.7	"	16
Hungarian wine	9.1	"	15
Italian	14	"	19
Syria, Corfu, Samos, Smyrna, Hebron, Lebanon	13	"	18

So various is the amount of alcohol in wines from the same district, that a very general notion only can be obtained by tables, and a sample of the wine actually used must generally be analyzed.

To tell how much pure alcohol is taken in any definite quantity of wine, measure the wine in ounces, multiply it by the percentage of alcohol, and divide by 100.

Example.—Wine drank being 9 oz., and the percentage 13, then $\frac{9 \times 13}{100}$

$= 1.17$ oz. of absolute alcohol by measure.

The amount of alcohol can be determined by distillation or evaporation, as given in the section on Beer. Instruments, however, are required, which indicate a less specific gravity than pure water. If the medical officer has only a common urinometer, the only plan will be to dilute with an equal part of pure water at 60°, and then to add a little salt, so as to bring the specific gravity above that of the water; then evaporate as usual. Take the difference of the specific gravities (before and after evaporation); deduct from 1000, and look in the specific gravity table (p. 297), for the amount of alcohol in the diluted wine; by multiplying the result by 2, the percentage of alcohol in the undiluted wine is found. Sometimes, besides ethyl alcohol, small quantities of propyl, butyl, and amyl alcohols are found in wine. A little acet-aldehyde is present in some Greek wines (Thudichum and Dupré), but is not considered to indicate unsoundness.[1]

2. *Ethers.*—Œnanthic, citric, malic, tartaric, racemic, acetic, butyric, caprylic, caproic, pelargonic, and many others. Dr. Dupré states that there are 25 or even more compound ethers in wine, and some of them are in very small quantities. The "bouquet" of wine is partly owing to the ethers (especially to the volatile)—partly, it is said, to extractive matters. Œnanthic ether is that which gives its characteristic odor to wine. Dr. Dupré has given a very good plan of estimating the amount of the volatile and non volatile ethers, but it is too delicate for medical officers.[2]

3. *Albuminous Matters—Extractive Coloring Matter.*—The quantity of albumen is not great; the extractives and coloring matter vary in amount. The coloring matter is derived from the skins; it is naturally greenish or blue, and is made violet and then red by the free acids of wine. The bluish tint of some Burgundy wines is owing, according to Mulder, to the very small amount of acetic acid which these wines contain. It is, according to Batilliat, composed of two matters—rosite and purpurite. With age

[1] If it is present in white wines (such as Sauternes) it is a certain sign of unsoundness.

[2] Chem. Journal, November, 1867, and Origin, Nature, and Use of Wine.

changes occur in the extractive matters; some of it falls (apothema), especially in combination with tannic acid, and the wine becomes pale and less astringent.

4. *Sugar* exists in varying amounts, and in the form for the most part of fruit sugar. Sherry generally contains sugar, but not always; it averages 8 grains per ounce;[1] and appears to be highest in the brown sherries, and least in Amontillado and Manzanilla. In Madeira it varies from 6 to 66 grains per ounce; in Marsala a little less; in Port, from 16 to 34 grains per ounce, being apparently greatest in the finest wines. In Champagne it amounts to from 6 to 28 grains, the average being about 24 grains. In the Clarets, Burgundy, Rhine, and Moselle wines, it is absent, or in small amount.

In determining the sugar, if the copper solution be used, the coloring matter is acted on by the alkali of the copper solution, and interferes with the appreciation of the change of tint, and must be got rid of by acetate of lead, animal charcoal, boiling, and filtering. If any substance exists which is still turned green by the alkali of the copper solution, the wine must be neutralized, evaporated to dryness, and the sugar dissolved. As a rule, the copper solution employed directly with wine gives ½ per cent. too much sugar (Fehling), and a correction to this amount should be made.[2]

5. *Fat.*—A small amount exists in some wines.

6. *Free Acids.*—Wine is acid from free acids and from acid salts, as the potassium bitartrate. The principal acids are racemic, tartaric, acetic, malic, tannic (in small quantities), glucic, succinic, lactic (?), carbonic, and fatty acids, such as formic, butyric, or propionic. Some acids are volatile besides the acetic, but it does not seem quite certain what they are. The tannic acid is derived from the skins; it is in greatest amount in new Port wines; it is trifling in Madeira and the Rhine wines; it is present in all white and most red-fruit wines, except Champagne. The tannic acid on keeping precipitates with some extractive and coloring matter (apothema of tannic acid).

7. *Salts.*—The salts consist of bitartrate of potassium, tartrates of calcium and sodium, sulphate of potassium, a little phosphate of calcium and magnesium, chloride of sodium, and iron. The magnesia is in larger amount than the lime, and exists sometimes as malate and acetate. A little manganese and copper have been sometimes found. In Rhine wine a little ammonia is found (Mulder). The total amount of salts is .1 to .3 per cent. —*i.e.*, about 9 to 26 grains per pint, or ½ to 1½ grain per ounce. The salts can only be detected by evaporation and ignition.

8. The total solids in wine vary from 3 to 14 per cent., or in some of the rich liqueur-like wines to more. The specific gravity depends upon the amount of alcohol and of solids, and varies from .673 to 1.002 or more. An approximate notion can be formed of the total solids by taking the specific gravity, after driving off the alcohol by evaporation and then replacing the water.

Examination of Wine.

The quality of wine can be best determined by noting the color, transparency, and taste, and then determining the following points:—

(1.) The amount of *solids* as given by the specific gravity after the elim-

[1] Bence Jones, in Mulder on Wine, p. 386.

[2] The addition of extraneous sugar to wine may be detected by the use of the saccharometer along with Fehling's solution.

ination of the alcohol. In the best clarets, before the loss of alcohol, the specific gravity is very nearly that of water. In some claret used in the Queen's establishment, and analyzed by Dr. Hofmann, the specific gravity was .99952. In other clarets it is as low as .995. A low specific gravity shows that alcohol has been added, or that the solids are in small amount.

(2.) The amount of *alcohol;* a very small amount may show the addition of water; a large amount the addition of spirits.

(3.) The amount of *free acidity.* This is an important point, as it seems clear that some persons (especially the sick) do not readily digest a large amount of acid and acid salts.

The amount is determined by the alkaline solution. The free acidity is generally reckoned as crystallized tartaric acid ($C_4H_6O_6$), 1 C.C. of the alkaline solution being equal to 7.5 milligrammes. There is both fixed and volatile acidity; the relative amount of the two is difficult to determine satisfactorily, as some acid may be formed on distillation. The distillation should be conducted at a low temperature, so as not to decompose the fixed compound ethers. The volatile acidity is reckoned as glacial acetic, the fixed as tartaric acid. All the acidities of wine are usually reckoned as grains per *ounce.*

The amount of free acidity varies greatly even in the same kind of wines; the least acid wines are Sherry, Port, Champagne, the best Claret, and Madeira; the more acid wines are Burgundy, Rhine wine, Moselle (Bence Jones). The amount of free acid in good Clarets is equal to 2 to 4 grains of tartaric acid per ounce; in common Clarets and in Beaujolais, it may be 4 to 6 grains, and in some extremely acid wines it may be even more than this. In the best Champagnes it is 2 to 3 grains usually; but it has been known to reach in excellent Champagne 1.12 per cent., or 4.8 grains per ounce.[1] In Port it averages 2 to 2½ grains, but may reach 4 grains; in Sherry 1½ to 2¼ grains; in the Rhine wines, 3½ to 4 or 6 grains. Thudichum and Dupré state that in good sound wine the amount of free acidity ranges from .3 to .7 per cent., or from 1.3 to 3 grains per ounce.

The taste of wine does not depend entirely on, but yet is very greatly influenced by, the degree of acidity. Mr. Griffin[2] states that good-tasted wine contains from 1.87 to 2.8 grains of crystallized tartaric acid per ounce; that if it contains less than 1.87 grain, it tastes flat; that if more than 3 grains per ounce, the wine is too acid to be agreeable; if more than 4.37 grains per ounce (1 per cent.), it is too acid to be drunk. These numbers seem rather low.[3]

(4.) The amount of *sugar.* The best modes of determining this have been already noticed.

(5.) It may be sometimes useful to determine the amount and kind of *ethers* by fractional distillation.

Excessive acidity of wine can be corrected by adding neutral potassium tartrate. Milk is also often used. The addition of the carbonated alkalies, or of chalk, alters the bouquet of the wine. When wine becomes stringy, in which case acetic and lactic acids are formed, it may be improved by adding a little tea; about 1 ounce of tea boiled in 2 quarts of water should

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[1] This was the case in some Champagne examined by Dr. Hofmann.

[2] Report on Cheap Wine, by R. Druitt, M.D., p. 178.

[3] From thirteen analyses of sound ordinary Port, I found the mean acidity to be 1.97 per ounce; in some samples of Sherry, 1.90; Marsala, 1.5; light Claret, 3.1; in a rather sour Claret, 4.0; in a sample of Montilla, a fine wine, but too acid, 3.15.—(F. de C.)

be added to about 40 gallons of wine. Bitter wine is treated with hard water or sulphur; bad-smelling wine with charcoal; too astringent wine with gelatin; wine which tastes of the cask with olive-oil.[1]

Adulterations of Wine.

1. *Water.*—Known by taste; amount of alcohol; specific gravity after elimination of alcohol.

2. *Distilled Spirits.*—Known by determining the amount of alcohol; the normal percentage of the particular kind of wine being known. By fractional distillations the peculiar-smelling fusel oils may be obtained; or merely rubbing some of the wine on the hand, and letting it evaporate, may enable the smell of these ethers to be perceived.

3. *Artificial Coloring Matters.*—The following are the chief coloring matters, as stated by Thudichum and Dupré. Logwood is the great coloring material, and also blackberries, elderberries, and bilberries. There are no good methods of recognizing these substances; salts of lead, ammonia, and ammonium sulphide, alum, and potassium or ammonium carbonate, and salts of tin, have been used as re-agents. The most useful test appears to be this: add to the wine about $\frac{1}{4}$th volume of strong solution of alum; stir well, and then add about an equal quantity of strong solution of ammonium carbonate; the natural coloring matter of the wine, when thrown down in this way, has a greenish or dirty bluish-green color, but there is no tinge of red; logwood and several other abnormal colors, have a distinct red or purplish tint.[2] The use of strips of gelatin, as described under Alum in BREAD, is also recommended. Fuchsine or rosaniline and other substances have also been used, but on the whole there has been some exaggeration, whilst the coloring matters employed are mostly harmless.

4. *Lime. Salts.*—The so-called "plâtrage" of wines consists in the addition of $1\frac{1}{2}$ lb to 7 lb of a mixture of calcium sulphate (80 parts), calcium carbonate (12), quicklime and sulphide and chloride of calcium (8 parts) to 1 hectolitre of wine. Calcium sulphate dissolves in large proportion, and then interchanges with the chloride of potassium, and chloride of calcium and sulphate of potassium are formed. The chalk forms acetate and tartrate of calcium. The proportion of lime salts is then very large. The only precise way of detecting this adulteration is by evaporating to dryness, incinerating, and determining the amount of lime. But the following method is shorter, and will generally answer. The natural lime salts of wine are tartrate and sulphate; when lime is added, an acetate of calcium is formed. Evaporate the wine to $\frac{1}{10}$th; add twice the bulk of strong alcohol; the calcium acetate is dissolved, but not the sulphate or tartrate; filter and test with oxalate of ammonium; if a large precipitate occur, lime has probably been added.

5. *Tannin* may be detected either by chloride of iron or by adding

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[1] Wine is subject to several diseases, which, according to Pasteur, depend on different kinds of ferments (see Review on Hygiene, in Army Medical Department Reports, vol. vii., p. 340). By heating the wine to about 125°–130° Fahr. these "mycoderms" are killed, and the wine undergoes no further change. The microscope may be employed, as in the case of Beer.

[2] Mulder speaks very doubtfully of all such tests; they seem, however, better than nothing. Probably the spectrum analysis will hereafter afford the best means of identification. On the coloring matter of wine, see Duclaux, Comptes Rendus de l'Académie des Sciences, t. lxxvii., No. 16, April, 1874, p. 1159; also Report on Hygiene, Army Med. Reports, vol. xv., p. 190.

gelatin; but as tannin exists naturally in most of the red wines (Port, Beaune, Roussillon, Hermitage, etc.), the question becomes often one of quantity. The amount of tannin can be estimated by drying the tanno-gelatine (100 grains contain 40 of tannin).

6. *Alum.*—This is detected precisely in the same manner as in bread. Evaporate a pint of the wine to dryness; incinerate, and then proceed as directed in BREAD.

7. *Lead.*—Evaporate to dryness, and incinerate; dissolve in dilute nitric acid, and test as directed in the EXAMINATION OF WATER.

8. *Copper.*—Decolorize with animal charcoal, and test at once with ferrocyanide of potassium.

9. *Cider and Perry.*—Evaporate wine, and the peculiar smell of the liquids will be perceived.

Port wine, as sold in the market, is stated to be a mixture of true Port, Marsala, Bordeaux, and Cape wines with brandy, although at present it is probably purer than it used to be—purer, perhaps, than most other wines. Inferior kinds are still adulterated with logwood, elderberries, catechu, prune juice, and a little sandalwood and alum. Receipts are given in books for all sorts of imitation wines.

SUB-SECTION III.—SPIRITS.

The Queen's *Regulations for the Army* (1881, sec. 15, paragraph 60) forbid the sale of spirits in canteens at home, but permit it in foreign stations at the discretion of the commanding officer.

Brandy contains, besides alcohol, œnanthic ether, acetic, butyric, and valerianic ethers. Tannin, and coloring matter from the cask, or from caramel, are present. If sugar is present in any quantity, it must have been added. The inferior kinds of brandy, prepared from potatoes as well as grain, contain potato fusel-oil. Rum contains a good deal of butyric ether, to which the aroma is chiefly owing. Gin, besides containing the oil of juniper, is flavored with various aromatic substances, as *Calamus aromaticus*, coriander, cardamoms, cinnamon, almond-cake, and orange-peel; Cayenne is often added. Whiskey often derives a peculiar flavor from the malt being dried over peat fires, or by the direct impregnation of peat smoke.[1] Peach stones and pine sawdust are also said to be added.

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[1] It may be worth while to give the names of some of the distilled spirits used in different parts of the world, as the army surgeon may meet with them in the course of service:—

Nations by whom employed.	Name.	Obtained from
Hindus, Malays, etc.	Arrack.	Rice or Areca-nut.
Greeks, Turks, etc	Raki.	Rice.
Hindus	Toddy.	Cocoa-nut.
" (Mahrattas)	Bojah.	Eleusine Corocana.
" (Sikkim)	Murwa.	" "
Chinese	Samshoo.	Rice.
Japanese	Sácie.	....
Pacific Islanders	Kawa.	Macropiper.
Mexicans	Pulque.	Agave.
South Americans	Chica.	Maize.
Tartars	Koumiss.	Mares' milk.
Russians and Poles	Voldki.	Potato.
Abyssinians	Talah.	Millet.

Composition of Spirits.

The following table gives the chief points of importance :[1]

Name.	Sp. gr. at 62° F.	Alcohol per cent.	Solids per cent.	Ash per cent.	Acidity per ounce, reckoned as tartaric acid.	Sugar per cent.
Brandy............	.929–.934	50–60	1.2	.05 to 0.2	1 grain	0 or traces
Gin...............	.930–.944	49–60	0.2	0.1	0.2 "	1
Whiskey...........	.915–.920	50–60	0.6	trace	0.2 "	0
Rum..............	.974–.926	60–77	1.0	0.1	0.5 "	0

Alcohol as an Article of Diet in Health.[2]

In endeavoring to determine the dietetic value of alcoholic beverages, it is desirable to see, in the first place, what are the effects of their most important constituent, viz., alcohol.

Three sets of arguments have been used in discussing this question, drawn, namely, from—1, the physiological action of alcohol ; 2, experience of its use or abuse ; and 3, moral considerations.

The last point will not be further alluded to, for without underrating the great weight of the argument drawn from the misery which the use of alcohol produces,—a misery so great that it may truly be said, that if alcohol were unknown, half the sin and a large part of the poverty and unhappiness in the world would disappear,—yet this part of the subject is so obvious that it seems unnecessary to occupy space with it. The arguments, however, which are strongest for total abstinence, are drawn from this class. Nor does any one entertain a moment's doubt that the effect of intemperance in any alcoholic beverage is to cause premature old age, to produce or predispose to numerous diseases, and to lessen the chance of living very greatly. The table given below,[3] taken from Neison's *Vital Statistics*, puts this in a strong light.

[1] This table is chiefly taken from Bence Jones' Observations ; Appendix to Mulder on Wine, p. 389 ; and from Hassall's Food and Adulteration, p. 645.

[2] The subject of spirits in sickness is another point altogether. Dr. Parkes believed they were often of great use, although, like every other strong medicine, they require to be given carefully.

[3] Effects of Intemperance (Neison's Statistics, p. 217 et seq.) :—

Ratio per cent. from the under-mentioned Causes, to Deaths from all Causes.

Cause of Death.	1847.	Gotha Life Office.	Scottish Widows' Fund.	Intemperate Lives.
Head diseases	9.710	15.176	20.720	27.10
Digestive organs (especially those of the liver).................	6.240	8.377	11.994	23.3
Respiratory organs	33.150	27.843	23.676	22.98
Total of above three classes...	49.100	51.396	56.390	73.38

It thus appears that the intemperate have a much greater mortality from head and digestive diseases than other classes.

The physiological argument for the use or disuse of alcohol requires to be used with caution, as our knowledge of the action of pure alcohol (much more of the alcoholic beverages) is imperfect.

When taken into the stomach, alcohol is absorbed without alteration, or is perhaps in some small degree converted into acetic acid, possibly by the action of the mucus or secretion of the stomach. The rate of absorption is not known, and it has been supposed that when given in very large quantities it may not be absorbed at all. It has not, however, been

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In intemperate persons the mortality at 21–30 years of age is five times that of the temperate; from 30–40 it is four times as great. It becomes gradually less.

A Temperate person's chance of living is,	An Intemperate person's chance of living is,
At 20 = 44.2 years.	At 20 = 15.6 years.
" 30 = 36.6 "	" 30 = 13.8 "
" 40 = 28.8 "	" 40 = 11.6 "
" 50 = 21.25 "	" 50 = 10.8 "
" 68 = 14.285 "	" 60 = 8.9 "

All these deductions appear to be drawn from observations on 357 persons, with 6,111.5 years of life. The facts connected with these persons are well authenticated, but the number is small.

The average duration of life after the commencement of the habits of intemperance is—

Among mechanics, working and laboring men	18 years.
" traders, dealers, and merchants	17 "
" professional men and gentlemen	15 "
" females	14 "

Those who are intemperate on spirits have a greater mortality than those intemperate on beer.

Those who are intemperate on spirits and beer have a slightly greater mortality than those intemperate on only spirits or beer, but the difference is immaterial.

	Mortality per annum.
Spirit drinkers	5.996 per cent. (nearly 60 per 1,000).
Beer drinkers	4.597 per cent. (nearly 46 per 1,000).
Spirit and beer drinkers	6.194 per cent. (nearly 62 per 1,000).

Very striking evidence in favor of total abstinence, as contrasted with moderation, is given by the statistics of the United Kingdom Temperance and General Provident Institution. One section consists of abstainers, another of persons selected as not known to be intemperate. The claims for five years (1860–70), anticipated in the Temperance section, were £100,446; but there were actually only claims for £72,676. In the general section, the anticipated claims were £196,352; and the actual claims were no less than £230,297. The much greater longevity of the abstainer is better seen by the amount of bonuses paid to each £1,000 whole-life policy in the two sections for the same five years.

Age at Entrance.	Premiums paid.	Bonus added in Temperance Section.	Bonus added in General Section.
	£ s. d.	£ s. d.	£ s. d.
15	83 2 6	61 1 0	35 10 0
20	93 6 8	64 0 0	37 0 0
25	106 9 2	68 10 0	40 0 0
30	122 1 8	74 0 0	43 0 0
35	138 19 2	78 19 0	46 0 0
40	162 5 10	86 0 0	50 4 0
45	188 10 10	92 18 0	54 0 0
50	226 5 0	104 2 0	60 13 0
55	284 3 4	122 14 0	71 11 0

recovered from the fæces in any great amount. After absorption it passes into the blood and then throughout the body; if the observations of Schulinus [1] are correct, it is equally distributed, and does not accumulate, as was formerly supposed, in the liver and nervous tissue. It can easily be detected in all the organs soon after it is taken. It commences to pass out from the body speedily, as it may be detected in the breath soon after it is taken; it emerges by the lungs, by the skin, in smaller quantities by the urine, and slightly by the bowels, or this may be merely from unabsorbed portions passing out. The amount recoverable from all these channels is usually small,[2] but occasionally, when very large quantities have been taken, the kidneys excrete it largely, so that the specific gravity of the urine has been below that of water, and distillation has given an inflammable fluid.[3]

Much debate has taken place as to whether all or how much of the alcohol is thus eliminated, and whether any is destroyed in the body. The experiments of Dr. Percy, and subsequently of Strauch, and especially of Masing in Buchheim's laboratory at Dorpat, followed as they were by the confirmatory observations of MM. Perrin, Lallemand, and Duroy, seemed at one time to have settled the question, and to have proved that alcohol is very little or not at all destroyed in the body. Since then the criticisms and experiments of Baudot, and especially the observations of Schulinus,[4] Anstie,[5] Dupré, and Subbotin, have again altered the position, and although the experimental evidence is incomplete (chiefly on account of the difficulty of collecting the amount given off by the lungs and skin), the opinion that some, and perhaps much, alcohol disappears in the body is generally admitted.[6]

At every age, therefore, the abstainer has a very great advantage. Mr. Vivian, the President of the Temperance and General Provident Institution, brought before the British Association at Bristol, in 1875, the following statistics:

Years.	Abstinence Section.		General Section.	
	Expected.	Actual.	Expected.	Actual.
1866–70 (5 years)......... ...	549	411	1,008	944
1871–74 (4 years).............	561	390	994	1,033
Totals (9 years)........	1,110	801	2,002	1,977

On the Gold Coast, during the Ashantee War, the evidence (slight as it was) was decidedly in favor of the teetotallers.—(Parkes, On the Issue of a Spirit Ration, p. 28, 1875.)

[1] Archiv der Heilk., 1866, p. 97.

[2] Experiments on this point by Schulinus, Anstie, Dupré, Thudichum, and others, prove that ordinarily the urinary elimination is slight. When it becomes at all marked, or even when it occurs at all, the detection of alcohol by potassium bichromate and sulphuric acid has been proposed by Anstie as an indication of the point when as much alcohol has been taken as can be disposed of by the body.

[3] A good case is given by Dr. Woodman (Medical Mirror, July, 1865).

[4] Archiv der Heilk., 1866.

[5] Lancet, 1868.

[6] The amount eliminated by these channels has been variously stated. The latest observations are by Dupré,[7] Anstie, and Subbotin.[8] According to Dupré, from experiments on himself, the amount eliminated by the urine and breath (he did not examine

[7] Proceedings of Royal Society, No. 138 (p. 268, 1872).

[8] Zeitschrift für Boil., Band vii., p. 361 (1872).

If alcohol is destroyed in the body, through what stages does it pass? The statement of Duchek, that it forms aldehyde, has been disproved. Its easiest transformation out of the body is into acetic acid; but, when animals are poisoned with alcohol, Buchheim and Masing could detect no acetic acid in the blood; still, the amount would be so small it might be overlooked, or the acetic acid might be soon transformed. Lallemand, Perrin, and Duroy could find no oxalic acid. If it be true that the pulmonary carbonic acid is lessened, it cannot be oxidized to carbonic acid and eliminated by the lungs unless the transformation of some other substance ordinarily furnishing carbonic acid is arrested. The mode of destruction is, in fact, unknown. The only point which throws any light upon it is the slight increase of acidity in the urine during the use of alcohol, which looks as if an acid of some kind were formed out of it.

Present experiments show, then, that some portion passes out, and another, and probably the larger portion, is gradually destroyed. The place where the partial destruction of alcohol occurs is yet doubtful; but it is impossible that the transformation takes place in the various gland-cells in which almost all, or all, the changes in the body take place. As the change out of the body which most easily occurs is the formation of acetic acid, it seems at present most likely that some of the alcohol is thus

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the skin) is only a minute fraction of that taken in, and it takes place chiefly in the first nine hours; subsequently the amount is excessively small. When taken day after day there is no accumulation of alcohol, so that the inference is, that as so little is eliminated almost all must be destroyed. Subbotin's experiments were on rabbits enclosed in a closed chamber through which the air was slowly drawn. Like Dupré, he determined the amount by oxidizing the alcohol obtained into acetic acid by chromic acid; but he found that not inconsiderable quantities (*nicht unbeträchtliche Mengen*) were eliminated through the lungs, and skin, and kidneys in the first five hours. Contrary to Perrin, Lallemand, and Duroy, he found twice as much passed from skin and lungs as from the kidneys. In 11 hours he found 12.6 per cent. was eliminated, and in 24 hours 16 per cent., and he gives reasons for supposing that the difficulties of the experiments (viz., the difficulty of changing all the alcohol into acetic acid; of obtaining the alcohol from the chamber; of regulating the ventilation; and by the diminution of absorption at the end of the experiment, and by the limited time the experiment could be carried on) made the amount actually recovered far less than it should have been. Anstie made numerous experiments on the urine and sweat, and always found the quantities very minute.

With regard to the length of time the elimination goes on, Dupré found it to be finished within a few hours; Subbotin found that the elimination was not quite ended in 24; Perrin, Lallemand, and Duroy, found it to go on for 32 hours. The late Dr. Parkes and Count Wollowicz found that minute quantities could be found in the urine even on the fifth day after a large quantity of brandy had been taken, though the elimination by the lungs ceased much sooner. In some later experiments, with small quantities of beer and wine, Dr. Parkes found the elimination to be finished in 24 hours.

Lieben noticed some years ago, that a substance which had some of the characters of alcohol was found in the urine of persons and animals who had taken none. Dr. Parkes and Count Wollowicz noticed on one occasion that a substance which slightly reduced chromic acid was obtained from the sweat of a man who had taken no alcohol,[1] though in other cases (E. Smith, British Medical Journal, November 2, 1861) there is certainly no substance of this kind in the sweat. Dupré also found in the urine a substance furnishing acetic acid, forming iodoform, and having a lower specific gravity and a higher vapor tension than pure water. The amount of this substance is so minute that its nature cannot be perfectly made out, but Lieben considers it not to be alcohol, but perhaps to be derived from the odoriferous principles of the urine. Dupré doubts this, and Dr. Parkes' observation on the sweat shows that it can hardly be so, unless the same odorous substances are passing off by the skin. Dr. Parkes doubted whether it was an invariable constituent of urine, as he could find none in the urine of three teetotallers which were examined.

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[1] Proceedings of Royal Society, No. 113, p. 87 (1870).

transformed. The acetic acid would then unite with the soda of the blood, and a carbonate would eventually be formed which would be eliminated with the urine, as in the case when acetates are taken.[1] This would account for the pulmonary carbonic acid not being increased. If this view be correct, the use of alcohol in nutrition would be limited to the effects it produces, first as alcohol, and subsequently as acetic acid, when it neutralizes soda, and is then changed into carbonate.

The first point only (its effect as alcohol) need be considered—

Influence of Alcohol on the Organs.

1. *On the Stomach.*—In very small quantities it appears to aid digestion; in larger amount it checks it, reddens the mucous membrane, and produces the "chronic catarrhal condition" of Wilson Fox—viz., increase of the connective tissue between the glands; fatty and cystic degeneration of the contents of the glands, and finally, more or less atrophy and disappearance of these parts.[2] Taken habitually in large quantities, it lessens appetite.

2. *On the Liver.*—The action of small quantities on the amount of bile or glycogenic substances, or on the other chemical conditions of the liver, is not known. Applied directly to the liver by injection into the portal vein, it increases the amount of sugar (Harley). Taken daily in large quantities, it causes either enlargement of the organ by producing albuminoid and fatty deposit, or it causes at once, or following enlargement, increase of connective tissue, and finally, contraction of Glisson's capsule, and atrophy of the portal canals and cells, by the pressure of a shrinking exudation. The exact amount necessary to produce these changes in the liver and stomach has not yet been fixed with precision.

3. *On the Spleen.*—Its action is not known.

4. *On the Lungs.*—It is said to lessen the amount of carbon dioxide (and of watery vapor?) in the air of expiration,[3] though there are some discrepancies in experiments with different kinds of spirits. E. Smith, for example, found the expired carbon dioxide lessened by brandy and gin, but increased by rum. It is very important these experiments should be repeated, but they show, at any rate, that the usual effect is not to increase the carbon dioxide.[4] In large quantities habitually taken it also alters the molecular constitution of the lungs, as chronic bronchitis and lobar emphysema are certainly more common in those who take much alcohol.

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[1] In experiments on large quantities of alcohol, Dr. Parkes found the acidity of the urine slightly increased. This would quite agree with the above view, as the union of the acetic acid or carbonic acid formed from it, with some of the alkali ordinarily united to other acids, would increase the urinary acidity. This case is, of course, not parallel with that of acetate of potash given by the mouth, which makes the urine alkaline from carbonate, as some alkali in that case is introduced.

[2] These changes were considered by Wilson Fox to be closely allied with those occurring in cirrhosis of the liver, and in the contracted and indurated kidney. See Diseases of the Stomach, 3d edition, p. 125, foot-note; and also Reynolds' System of Medicine, vol. ii., p. 869, and foot-note.

[3] The effect of red and white French wines and of beer has been very carefully examined by Perrin (Rec. de Mém. de Méd. Mil., 1865, p. 82); a very great diminution in the amount of carbonic acid (from 5.6 to 22 per cent. less being excreted) was noticed in all the experiments. The effect commenced soon, and reached its maximum in the third hour, and ceased in two hours more. The pulse after meals with and without wine had equal power, but after a time the pulse fell more when wine was not taken.

[4] See Binz, Journal of Anatomy and Physiology, May, 1874.

5. *On the Heart and Blood-Vessels.*—Alcohol in healthy persons at first increases the force and the quickness of the heart's action. Dr. Anstie[1] confirmed this opinion by careful sphygmographic observations; these effects are still more marked in febrile diseases if alcohol acts favorably (in some febrile cases it appears, from Anstie's observations, not to increase the power of the heart). In a healthy man, Dr. Parkes found that brandy[2] augmented the rapidity of the pulse 13 per cent., and the force was also increased; taking the usual estimate of the heart's work, its daily excess of work, with 4.8 fluid ounces of absolute alcohol, was equal to 15.8 tons lifted one foot. With claret the results were almost identical. The period of rest of the heart was shortened, and its nutrition must therefore have been interfered with. In another man, Dr. Parkes found from 4 to 8 ounces of brandy produced palpitation and breathlessness. Alcohol causes evident dilatation of the superficial vessels, as shown by the redness and flushing of the skin; and in these experiments sphygmographic observations also proved that the arteries dilated more easily before the fuller current thrown out by the strongly acting heart. If it were not for this yielding of the vessels (produced perhaps by paralysis of the vasomotor nerves) alcohol would be a most dangerous agent, as either the strong wave would break the vessel, or the heart would not be properly emptied of the blood during the contraction. It seems likely, therefore, that there must be danger in the use of alcohol when the arteries become rigid in advancing life, if the heart is then susceptible to the action of alcohol. Eventually the vessels of the surface pass into a state of permanent slight enlargement and turgescence; the skin alters in appearance; and owing to this, persons who take much alcohol soon get the appearance of age. In some diseases, alcohol is said to lessen the frequency of the heart's action; and Anstie found it increase arterial tension. In such cases there must be peculiar nervous conditions with which we are unacquainted. Dr. Parkes found it usually, if not always, increase the frequency of the heart in disease, and in some patients the rapidity of the heart's action was simply owing to the administration of alcohol. Anstie believed its principal action was on the sympathetic nerve, and the vascular phenomena seem to strengthen this view, while others think it acts especially on the vagus and the heart alone.

6. *On the Blood.*—The amount of fat is either increased, or it is more visible. The chemical changes in the blood are partially arrested.[3]

7. *On the Nervous System.*—In most persons it acts at once as an anæsthetic, and lessens also the rapidity of impressions, the power of thought, and the perfection of the senses. In other cases it seems to cause increased rapidity of thought, and excites imagination; but even here the power of control over a train of thought is lessened. In no case does it seem to increase accuracy of sight; nor is there any good evidence that it quickens hearing, taste, smell, or touch; indeed, Edward Smith's experiments show that it diminishes all the senses. In almost all cases moderate quantities cause a feeling of comfort and exhilaration, which ensues so quickly as to

[1] In a paper read before the British Association in 1868 (Medical Times and Gazette, September, 1868). This paper shows that the sphygmographic indications (combined with the urinary test) may give us a clue to the often difficult question, whether alcohol is doing good or harm in disease.

[2] See papers by Dr. Parkes and Count Wollowicz, in Proceedings of Royal Society, Nos. 120 and 132; and another paper by Dr. Parkes, No. 136, for the effect of alcohol on the heart during exercise.

[3] Harley, Proceedings of Royal Society, March, 1865, No. 62, p. 160.

make it probable the local action on the nerves of the stomach has at first something to do with this. Afterward the increased action of the heart may have an effect. Different spirits act differently on the nervous system, owing probably to the presence of ethers and oils; some, as samshoo[1] and raki, produce great excitement, followed by profound torpor and depression. Absinthe is also especially hurtful, apparently from the presence of the essential oils of anise, wormwood, and angelica, as well as from the large amount of alcohol. It appears that the properties of absinthe are somewhat different according to the manner in which water is mixed with it, *i.e.*, suddenly or slowly; in the latter case the particles of the absinthe are more divided, are absorbed more easily, and produce greater effects. In all these cases there can be little doubt that alcohol enters into temporary combination with the nervous structure; and the evidence from the impairment of special sense and muscular power, implies that it interferes with the movements of the nervous currents.

8. *On the Muscular System.*—Voluntary muscular power seems to be lessened, and this is most marked when a large amount of alcohol is taken at once; the finer combined movements are less perfectly made. Whether this is by direct action on the muscular fibres, or by the influence on the nerves, is not certain. In very large doses it paralyzes either the respiratory muscles, or the nerves supplying them, and death sometimes occurs from the impairment to respiration.

9. *On the Metamorphosis of Tissue.*—This is usually stated to be lessened, and it has been said that there is a diminution in the elimination of nitrogen (as urea), and of carbon (as carbon dioxide). But the experiments already referred to by Count Wollowicz and Dr. Parkes[2] prove that the metamorphosis of the nitrogenous tissues is in no way interfered with by dietetic doses. Whether the carbonic dioxide excretion is really lessened may also be questioned.

10. *On the Temperature of the Body.*—When alcohol is given to healthy animals in full but not excessive doses, the temperature of the body falls. This seems to be shown conclusively by the experiments of Ringer and Rickards, Richardson, Binz, Cuny-Bouvier, and Ruge. In healthy men who have been accustomed to take alcohol in moderate quantities, the results are rather contradictory. In a man accustomed to alcohol, Ringer found no change; in two men, temperate, but accustomed to take beer and sometimes spirits, Dr. Parkes could not detect any raising or lowering of the thermometer either in the axilla or rectum.[3] Dr. Mainzer found no fall of temperature[4] in trials on himself, but a slight fall in another healthy person. Some experiments by Obernier[5] and by Fokker[6] are

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[1] Dr. Dupré analyzed for Dr. Parkes a specimen of the best samshoo from Singapore. It contained in 100 C.C. 23.91 per cent. of alcohol by weight, and this was made up of 23.874 parts of ethyl alcohol, and .036 part of amylic alcohol; the amount of free acid (almost all acetic) was .105; of residue (sugar almost entirely), 6.01, and of ash, .06 per cent. Cheap samshoo gave nearly the same result. There seems to be nothing deleterious here; and from inquiries among soldiers who have served at Hong-Kong, it seems doubtful whether good samshoo does produce the effects ascribed to it. It is probably the adulterated (with opium, etc.) article which acts so violently. The Cape brandy is of two kinds—the Cape and the Boer brandy; the latter is stronger, and is sometimes called peach brandy; this appears to be the hurtful kind.

[2] Proceedings of Royal Society, Nos. 120–123 and 136.

[3] Ibid.

[4] Ueber die Einwirkung des Alkohols, Inau. Diss. Bonn., 1870.

[5] Archiv für die ges. Phys., Band ii., p. 494.

[6] Quoted by Husemann, Jahresb. für die ges. Med., 1871, Band i., p. 324.

also quite negative. On the other hand, Ringer, Binz, and Bouvier noticed in some healthy persons a decrease of temperature; and though some of the experiments are evidently rather inaccurate, and though the fall of temperature was inconsiderable, it is difficult to refuse belief that in some cases there may be a slight depression of temperature.[1]

In febrile cases the evidence is almost equally divided. In a man on whom Dr. Parkes was experimenting, an attack of catarrh came on with rise of temperature, and alcohol did not apparently affect the heat in the least. O. Weber, Obernier, and Rabow were equally unsuccessful in noting a fall in temperature. Binz and C. Bouvier[2] have, however, produced septic fever in animals, and then lowered the febrile heat by large doses of alcohol, in what appears to have been an unmistakable manner, in several cases.

We may conclude that the effect of moderate doses on temperature in healthy men is extremely slight; there is no increase, and in many persons no decrease. In those in whom there is a slight decrease, the amount is trifling.

11. *On the Action of the Eliminating Organs.*—The water of the urine and the acidity are slightly increased; but Dr. Parkes found other ingredients were unaffected. The condition of the skin is not certain. Dr. E. Smith thought the perspiration lessened, but Weyrich noticed, after spirits, beer, and wine, a large increase in the insensible cutaneous perspiration; and the enlargement of the vessels of the skin would probably lead to increased transit of fluid.

12. *Remote Effects of Alcohol.*—The degenerative changes which occur so frequently in the stomach, liver, and other organs, by the constant introduction of improper quantities of alcohol into the body,[3] affect also almost all parts of the body. The brain and its membranes, and its vessels, suffer early and principally; and Kremiansky[4] has produced hemorrhagic meningitis and pathological changes in the brain-vessels and membranes in dogs by giving them alcohol.[5] There is no question that several brain diseases, including some cases of insanity, are produced by excess of alcohol.[6] So, also, degenerative changes in the stomach, liver, lungs, and probably in the kidneys,[7] result from immoderate use. To use Dickinson's expressive phrase, alcohol is the very "genius of degeneration." And these alcoholic degenerations are certainly not confined to the notoriously intemperate. They have been seen in women accustomed to take wine in

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[1] Binz (loc. cit.) finds that small (dietetic ?) doses produce no change; large inebriating doses produce a fall from 3.5° to 5° F., lasting for four or five hours. Habit, however, produces tolerance. In the body, after death, the temperature often rises, but if alcohol has been administered previously it does not do so; hence Binz concludes that the effect is arrest of chemical changes in the glands.

[2] See especially Pharmakologische Studien über den Alkohol, von C. Bouvier, Berlin, 1872.

[3] A very striking paper on this subject has been published by Dickinson (Lancet, November, 1872). It paints, in startling colors, the immense degenerative power of alcohol.

[4] Virchow's Archiv, Band xlii., p. 338.

[5] See also the experiments by Magnan (Sur l'Alcoolisme).

[6] Magnan states the two determinations of chronic alcoholism to be *dementia* and *general paralysis*.

[7] Anstie and Dickinson have denied that the kidneys suffer in alcoholism in any great degree. It is an open question; but the evidence is in favor of kidney degeneration being one of the effects of alcoholism. Dr. George Johnson states that out of 200 patients with Bright's disease, from all causes, he found no less than 58 were drunkards.

quantities not excessive, and who would have been shocked at the imputation that they were taking too much, although in their case the result proved that for them it was excess. The nature of the degenerative changes appears to be in all cases the same, viz., fibroid and fatty changes.

Considering, also, the great increase in the action of the heart, and the dilatation of the vessels, it can scarcely be doubted that alcohol in excess is one of the agencies causing disease of the circulatory organs.

Is Alcohol desirable as an Article of Diet in Health?

This question is so large and difficult that a satisfactory answer can hardly be given with our present knowledge. The data for passing a judgment are partly physiological, but still more largely empirical.

The obvious useful physiological actions of alcohol are an improvement in appetite, produced by small quantities, and an increased activity of the circulation, which, within certain limits, may be beneficial. It is difficult to perceive proof at present of any other useful action, since it is uncertain whether, during its partial destruction in the system, it gives rise to energy. In cases of disease, in addition to its effect on digestion and circulation, its narcotizing influence on the nervous system may be sometimes useful. Beale suggests that it may restrain the rapidity of abnormal growth or development of multiplying cells, and that by such arrest it may possibly diminish bodily temperature; but proof of this has not been given.

The dangerous physiological actions in health, when its quantity is larger, are evidently its influence on the nervous system generally, and on the regulating nerve-centres of the heart, and vaso-motor nerves in particular;[1] the impairment of appetite produced by large doses, the lessening of muscular strength, and remotely the production of degenerations. Except when it lessens appetite, it does not alter the transformation of the nitrogenous tissues, and the elimination of nitrogen; nor can it be held to be absolutely proved to lessen the excretion of carbon. If it did so, this effect in health would be simply injurious.

It is a matter of the highest importance to determine when the limit of the useful effect of alcohol is reached. The experiments are few in number, but are tolerably accurate. From experiments made by Dr. Anstie, an amount of one fluid ounce and a half (42.6 C.C.) caused the appearance of alcohol in the urine, which Anstie regards as a sign that as much has been taken as can be disposed of by the body. The late Dr. Parkes and Count Wollowicz obtained almost precisely the same result. When only one fluid ounce of absolute alcohol was given, none could be detected in the urine. They found that in a strong, healthy man, accustomed to alcohol in moderation, the quantity given in twenty-four hours that begins to produce effects which can be considered injurious, is something between one fluid ounce (= 28.4 C.C.) and two fluid ounces (56.8 C.C.). The effects which can then be detected are slight, but evident narcosis, lessening of appetite, increased rapidity of rise in the action of the heart, greater dilatation of the small vessels as estimated by the sphygmograph, and the

[1] This influence is probably a paralyzing agency, arising from a direct though transitory union of the alcohol with the nervous substance. Richardson has made the very important discovery that the alcohols, such as the butyl, amyl, and hexyl alcohols, which contain more carbon, produce a much greater effect on the nervous system than methyl and ethyl alcohol. There are greater muscular tremors and stupor, and these effects increase regularly with the increase of carbon and lessening volatility.

appearance of alcohol in the urine. These effects manifestly mark the entrance of that stage in the greater degrees of which the poisonous effect of alcohol becomes manifest to all.

It may be considered, then, that the limit of the useful effect is produced by some quantity between 1 and 1½ fluid ounce in twenty-four hours. There may be persons whose bodies can dispose of larger quantities ; but as the experiments were made on two powerful, healthy men, accustomed to take alcohol, the average amount was more likely to be over than under stated. In women, the amount required to produce decided bad effects must, in all probability, be less. For children there is an almost universal consent that alcohol is injurious, and the very small quantity which produces symptoms of intoxication in them indicates that they absorb it rapidly and tolerate it badly.

Assuming the correctness of these experimental data, which, though not extensive, are yet apparently exact, it is evident that moderation must be something below the quantities mentioned ; and considering the dangers of taking excess of alcohol, it seems wisest to assume 1 to 1½ fluid ounce of absolute alcohol in twenty-four hours as the maximum amount which a healthy man should take. It must be admitted that this is provisional, and that more experiments are necessary ; but it is based on the only safe data we possess. One ounce is equivalent to 2 fluid ounces of brandy (containing 50 per cent. of alcohol) or to 5 ounces of the strong wines (sherries, etc., 20 per cent. of alcohol) ; or to 10 ounces of the weaker wines (clarets and hocks, 10 per cent. of alcohol) ; or to 20 ounces of beer (5 per cent. of alcohol). If these quantities are increased one-half, 1½ ounce of absolute alcohol will be taken, and the limit of moderation for strong men is reached. This standard appears to be fairly correct ; since, from inquiries of many healthy men who take alcohol in moderation, Dr. Parkes found that they seldom exceeded the above amounts. Women, no doubt, ought to take less ; and alcohol in any shape only does harm to healthy children.

Another question now arises, to which it is more difficult to reply. Is alcohol, even in this moderate amount, necessary or desirable ; are men really better and more vigorous, and longer lived with it than they would be without any alcohol? If distinctly hurtful in large quantities, is it not so in these smaller amounts?

There is no difficulty in proving, statistically, the vast loss of health and life caused by intemperance ; and the remarkable facts of the Provident Institution show the great advantage total abstainers have over those who, though not intemperate, use alcohol more freely. But it is almost impossible, at present, to compare the health of teetotallers with those who use alcohol in the moderate scale given above. In both classes are found men in the highest health, and with the greatest vigor of mind and body ; in both are to be found men of the most advanced age. If the question is looked at simply as a scientific one, it is hardly possible at present to give an answer. Failing in accurate information on this point, the usual arguments for and against the use of alcohol cannot be held to settle the point. These are—

(*a*) That the universality of the habit of using some intoxicating drink proves utility. This seems incorrect,[1] since whole nations (Mohammedan and Hindoo) use no alcohol or substitute ; and since the same argument

[1] Most nations, however, if not all, use some sedative, which may be considered to take the place of alcohol.—(F. de C.)

might prove the necessity of tobacco, which for this generation, at any rate, is clearly only a luxury. The wide-spread habit of taking intoxicating liquids merely proves that they are pleasant.

(*b*) That if not necessary in healthy modes of life, alcohol is so in our artificial stage of existence amid the pressure and conflict of modern society. This argument is very questionable, for some of our hardest workers and thinkers take no alcohol. There are also thousands of persons engaged in the most anxious and incessant occupations who are total abstainers, and, according to their own account, with decided benefit.

(*c*) That though it may not be necessary for perfectly healthy persons, alcohol is so for the large class of people who live on the confines of health, whose digestion is feeble, circulation languid, and nervous system too excitable. It must be allowed there are some persons of this class who are benefited by alcohol in small quantities, and chiefly in the form of beer or light wine. Unless these persons wilfully deceive themselves, they feel better and are better with a little alcohol.

(*d*) That common experience on the largest scale shows that alcohol in not excessive quantities cannot be an agent of harm ; that it is and has been used by millions of persons who appear to suffer no injury, but to be in many cases benefited, and therefore that it must be in some way a valuable adjunct to food. A grand fact of this kind must, it is contended, override all objections based on physiological data, which are confessedly incomplete, and which may have left undiscovered some special useful action. It must be admitted that this is a very strong argument, and that it seems incredible that a large part of the human race should have fallen into an error so gigantic as that of attributing great dietetic value to an agent which is of little use in small quantities, and is hurtful in large. At first sight the common sense of mankind revolts at such a supposition, but the argument, though strong, is not conclusive ; and unfortunately we know that in human affairs no extension of belief, however wide, is *per se* evidence of truth.

(*e*) That though a man can do without alcohol under ordinary circumstances, there are certain conditions when it is useful. It will be necessary to see, then, what is the evidence on this point.

Evidence on the Use of Alcohol under certain Conditions.[1]

Great Cold.—There is singular unanimity of opinion on this point ; all observers condemn the use of spirits, and even of wine or beer, as a preventive against cold. In the Arctic regions we have on this head the evidence of Sir John Richardson, Mr. Goodsir (in Sir J. Franklin's first voyage), Dr. King, Captain Kennedy (in the last search for Sir J. Franklin, when the whole crew were teetotallers), Dr. Rae, Dr. Kane, Dr. Hayes (surgeon of the Kane expedition), and others. Dr. Hayes, indeed, says in his last paper (1859), that he will not only not use spirits, but will take no man accustomed to use them ; and that if "imperious necessity obliges him to give spirits, he will give them in small doses frequently, as the excitant action is followed by a very dangerous depression.[2] In the Antarc-

[1] See Carpenter's "Essay on Temperance," and his other writings, and also Spencer Thompson's useful work on the same subject, as well as many other writers.

[2] Some Arctic voyagers, however, are strongly impressed with the value of rum under certain circumstances (Admiral Richards). The experience of the expedition of 1875–76 seems to have shown that it was partially useful given the last thing at night, as enabling the men to get off their frozen clothing, but it had no effect in warding off scurvy. Binz says that alcohol may be useful in damp and cold, because the tissue change is greater, and we can thus moderate it.

tic regions, and in the cold whaling grounds, we have the strong evidence of Dr. Hooker to the same purport, and the customs of the many teetotal whalers. Ulloa long ago noticed the same thing in the ascent of Pichincha.[1] In North America, the Hudson's Bay Company entirely excluded spirits, partly, no doubt, to prevent their use among the Indians, but partly, in all probability, from experience of their inutility. Dr. Carpenter quotes from Dr. Knüll a statement that the Russian army on the march in cold weather not only use no spirits, but no man who has lately taken any is allowed to march. The guides at Chamouni and the Oberland, when out in the winter, have invariably found spirits hurtful; they take only a little light wine (Forbes). The bathing men at Dieppe, who are much exposed to cold from long standing in the sea, also find that spirits are hurtful, and take only a little weak wine (Lévy).

Great Heat.—The evidence here also is almost equally conclusive against the use of spirits or beverages containing much alcohol. Dr. Carpenter has assembled the most conclusive testimony from India, Brazil, Borneo, Africa, and Demerara. The best authorities on tropical diseases speak as strongly; Robert Jackson, Ranald Martin, Henry Marshall, and many others. It seems quite certain, also, that not only is heat less well borne, but that insolation is predisposed to.

The common notion that some form of alcoholic beverage is necessary in tropical climates is a mischievous delusion. In the 84th Regiment, in which Dr. Parkes formerly served, which from the years 1842 to 1850 numbered many teetotallers (at one time more than 400) in its ranks, the records showed that, both on common tropical service and on marches in India, the teetotallers were more healthy, more vigorous, and far better soldiers than those who did not abstain.[2] The experience of almost every hunter in India will be in accordance with this.

On this point the greatest army surgeons have spoken strongly (Jackson especially, and Martin); and yet officers may still be heard, both in India and the West Indies, to assert that the climate requires alcohol. These are precisely the climates where alcohol is most hurtful.[3]

With regard to service and exercise in the tropics, we have the strong testimony of Ranald Martin that warm tea is the best beverage; and this will be corroborated by every one who has made long marches, or hunting excursions, in India, and has carefully observed what kind of diet best suited him.

To cite a well-known individual instance of great exertion in a hot climate, Robert Jackson marched 118 miles in Jamaica, carrying a load equal to a soldier's, and decided that "the English soldier may be rendered capable of going through the severest military service in the West Indies; and that temperance will be one of the best means of enabling him to per-

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[1] He says (Adams' translation, 1807, vol. i., p. 219): "At first we imagined that drinking strong liquors would diffuse a heat through the body, and consequently render it less sensible of the painful sharpness of the cold; but to our surprise we felt no manner of strength in them, nor were they any greater preventative against the cold than common water."

[2] See Carpenter's Physiology of Temperance for full details. The officers, who by their example and precept produced this great effect in a regiment in India, and proved that men are healthier and happier in India without any alcoholic beverage, were Lieut.-Colonel Willington, Captain (afterward General Sir David) Russell, and Lieut. and Adjutant Seymour, an officer of the greatest promise, who died from dysentery, contracted during the mutiny.

[3] Binz holds that in hot climates, or in hot weather, it is pernicious, as interfering with the tissue change, which is already insufficient.

form his duty with safety and effect. The use of ardent spirits is not necessary to enable a European to undergo the fatigue of marching in a climate whose mean temperature is from 73° to 80°. I have always found the strongest liquors the most enervating."

Bodily Labor.—A small quantity of alcohol does not seem to produce much effect, but more than two fluid ounces manifestly lessens the power of sustained and strong muscular work. In the case of a man on whom Dr. Parkes experimented, 4 fluid ounces of brandy (=1.8 fluid ounce of absolute alcohol) did not apparently affect labor, though it could not be affirmed it did not do so; but 4 ounces more given after four hours, when there must have been some elimination, lessened muscular force; and a third 4 ounces, given four hours afterward, entirely destroyed the power of work. The reason was evidently twofold. There was, in the first place, narcosis and blunting of the nervous system—the will did not properly send its commands to the muscles, or the muscles did not respond to the will; and secondly, the action of the heart was too much increased, and induced palpitation and breathlessness, which put a stop to labor. The inferences were, that even any amount of alcohol, although it did not produce symptoms of narcosis, would act injuriously by increasing unnecessarily the action of the heart, which the labor alone had sufficiently augmented.[1] These experiments are in accord with common experience, which shows that men engaged in very hard labor, as iron-puddlers, glass-blowers, navvies on piece-work, and prize-fighters during training, do their work more easily without alcohol.

In the exhaustion following great fatigue, alcohol may be useful or hurtful according to circumstances. If exertion must be resumed, then the action of the heart can be increased by alcohol and more blood sent to the muscles; of course, this must be done at the expense of the heart's nutrition, but circumstances may demand this. In the case of an army, for example, called on to engage the enemy after a fatiguing march, alcohol might be invigorating. But the amount must be small, *i.e.*, much short of producing narcosis (not more than ½ fluid ounce of absolute alcohol), and, if possible, it should be mixed with Liebig's meat extract, which, perhaps on account of its potash salts, has a great power of removing the sense of fatigue.

About two ounces of red claret wine with two teaspoonfuls of Liebig's extract and half a pint of water is a very reviving draught, and if it could be issued to troops exhausted by fatigue, would prove a most useful ally.

But when renewed exertion is not necessary it would appear most proper after great fatigue to let the heart and muscles recruit themselves

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[1] In experimenting on another healthy man the following interesting result was obtained. The exercise and diet being uniform during a period of ten days, the mean daily pulse (nine two hourly observations) was 70.65. Severe exercise being then taken during another period of ten days for two hours in the morning, in addition to what had previously been taken, the pulse in those two hours was augmented 16 beats per minute over the corresponding period; it fell, however, in the subsequent hours below the mean of the corresponding period, so that the mean pulse of the day was 70.42 per minute, the same as in the ten days' period before the additional exercise. The heart, in fact, completely compensated itself, and the work done by it was the same on days of moderate and of severe exercise. Now alcohol would have disturbed this adjustment, and would have kept the heart beating more rapidly than it should do. The compensation would not have been produced. In more recent experiments, in which the effects of rum, meat extract, and coffee were observed, it was found that marching was done least easily with rum, the stimulant effect passing quickly off, and leaving the man less able to finish the work before him.—(On the Issue of a Spirit Ration in the Ashantee Campaign, Parkes, 1875.)

by rest; to give digestible food, but to avoid unnecessary and probably hurtful quickening of the heart by alcohol.

Mental Work.—In spite of much large experience, it is uncertain whether alcohol really increases mental power. The brain circulation is no doubt augmented in rapidity; the nervous tissues must receive more nutriment, and for a time must work more strongly. Ideas and images may be more plentifully produced, but it is a question whether the power of clear, consecutive, and continuous reasoning is not always lessened. In cases of great exhaustion of the nervous system, as when food has been withheld for many hours and the mind begins to work feebly, alcohol revives mental power greatly, probably from the augmented circulation. But, on the whole, it seems questionable whether the brain finds in alcohol a food which by itself can aid in mental work.

Deficiency of Food.—When there is want of food, it is generally considered that alcohol has a sustaining force, and possibly it acts partly by keeping up the action of the heart, and partly by deadening the susceptibility of the nerves. It was formerly supposed that it lessened tissue-change, and thus curtailed the waste of the body; but this is not true of the nitrogenous tissues, and is not yet quite certain in respect of the carbonaceous. It seems unlikely that alcohol would be applied differently during starvation and during usual feeding.

Cases are recorded in which persons have lived for long periods on almost nothing but wine and spirits. In most cases, however, some food has been taken, and sometimes more than was supposed, and in all instances there has been great quietude of mind and body. It seems very doubtful whether in any case nothing but alcohol has been taken; and, in fact, we may fairly demand more exact data before weight can be given to this statement.

The Exposures and Exertions of War.—On this point also there is considerable unanimity of opinion. The greatest fatigues, both in hot and cold climates, have been well borne—have been, indeed, best borne—by men who took no alcohol in any shape, and some instances may be quoted.

In the American War of Independence in 1783, Lord Cornwallis made a march over 2,000 miles in Virginia, under the most trying circumstances of exposure to cold and wet; yet the men were remarkably healthy, and among the causes for this health, Chisholm states that the necessary abstinence from strong liquors was one.

In 1794–95 occurred the Maroon War in Jamaica, where almost for the first time in West Indian warfare the troops were remarkably healthy, though the campaign was very arduous, and in the rainy season, and there were no tents. The perfect health of the troops may partly have been owing to the climate of the hills (2,000 feet above the sea), but it was chiefly attributed to the fact that the men could obtain no spirits or alcoholic liquid of any kind.

In 1800 an English army proceeding from India to Egypt, to join Sir Ralph Abercromby, marched across the desert, from Kossier on the Red Sea, and descended the Nile for 400 miles. Sir James M'Grigor[1] says that the fatigue in this march has perhaps never been exceeded by any army, and goes on to remark:—

"We received still further confirmation of the very great influence which intemperance has as a cause of disease. We had demonstration how very

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[1] Medical Sketches of the Expedition to Egypt, p. 10.

little spirits are required in a hot climate to enable a soldier to bear fatigue, and how necessary a regular diet is.

"At Ghenné, and on the voyage down the Nile (on account of the difficulties of at first conveying it across the desert), the men had no spirits delivered out to them, and I am convinced that from this not only did they not suffer, but that it even contributed to the uncommon degree of health which they at this time enjoyed. From two boats the soldiers one day strayed into a village, where the Arabs gave them as much of the spirit which they distil from the juice of the date-tree as induced a kind of furious delirium. It was remarked that, for three months after, a considerable number of these men were in the hospitals."

Dr. Mann,[1] one of the few American surgeons in the war of 1813–14 who have left any account of that contest, thus writes :—

"My opinion has long been that ardent spirits are an unnecessary part of a ration. Examples may be furnished to demonstrate that ardent spirits are a useless part of a soldier's ration. At those periods during the revolutionary war, when the army received no pay for their services, and possessed not the means to procure spirits, it was healthy. The 4th Massachusetts Regiment, at the eventful period when I was the surgeon, lost in three years by sickness not more than five or six men. It was at a time when the army was destitute of money. During the winter 1779–80 there was only one occurrence of fever in the regiment, and that was a pneumonia of a mild form. It was observable in the last war, from December, 1814, to April, 1815, the soldiers at Plattsburg were not attacked with fevers as they had been the preceding winters. The troops during this period were not paid —a fortunate circumstance to the army, arising from want of funds. This embarrassment, which was considered a national calamity, proved a blessing to the soldier. When he is found poor in money, it is always the case that he abounds in health—a fact worth recording."

No testimony can be stronger than that given by the late Inspector-General Sir John Hall, K.C.B. He says[2] :—

"My opinion is, that neither spirit, wine, nor malt liquor is necessary for health. The healthiest army I ever served with had not a single drop of any of them ; and although it was exposed to all the hardships of Kaffir warfare at the Cape of Good Hope, in wet and inclement weather, without tents or shelter of any kind, the sick-list seldom exceeded one per cent. ; and this continued not only throughout the whole of the active operations in the field during the campaign, but after the men were collected in standing camps at its termination ; and this favorable state of things continued until the termination of the war. But immediately the men were again quartered in towns and fixed posts, where they had free access to spirits, an inferior species of brandy sold there, technically called 'Cape Smoke,' numerous complaints made their appearance among them.

"In Kaffraria the troops were so placed that they had no means of obtaining liquor of any kind ; and all attempts of the 'Winklers' to infringe the police regulations were so summarily and heavily punished by fines and expulsion, that the illicit trade was effectually suppressed by Colonel Mackinnon, the Commandant of British Kaffraria ; and the consequence was, that drunkenness, disease, crime, and insubordination were unknown ; and yet that army was frequently placed in the very position that the advocates for the issue of spirits would have said required a dram.

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[1] Hamilton, Military Surgery, p. 61.

[2] Medical History of the War in the Crimea, vol. i., p. 504.

"Small as the amount of sickness and mortality was in the Crimea, during the winter 1855–56, they would have been reduced one-half, I am quite sure, could the rule that was observed in Kaffirland have been enforced there."

In the same Kaffir war (1852), a march was made by 200 men from Graham's Town to Bloemfontein, and back; 1,000 miles were covered in seventy-one days, or at the rate of nearly 15 miles daily; the men were almost naked, were exposed to great variations of temperature (excessive heat during day; while at night water froze in a bell-tent, with twenty-one men sleeping in it); and got as rations only biscuit, meat 1½ ℔, and what game they could kill. For drink they had nothing but water. Yet this rapid and laborious march was not only performed easily, but the men were "more healthy than they had ever been before; and after the first few days, ceased to care about spirits. No man was sick till the end of the march, when two men got dysentery, and these were the only two who had the chance of getting any liquor."

In the last New Zealand war, Dr. Neill (Staff Assistant-Surgeon) found that the troops marched better, even when exposed to wet and cold, when no spirits were issued, than when there was a spirit ration.

In the expedition to the Red River, under Sir Garnet Wolseley, no alcoholic liquid was issued. Two accounts of this remarkable march have been published—one by Captain Huyshe,[1] and the other by an officer who wrote an interesting account of the march in *Blackwood's Magazine*.[2] Captain Huyshe says:—

"Although it was an unheard-of thing to send off an expedition into a wilderness for five months without any spirits, still as the backwoodsman was able to do hard work without spirits, it was rightly thought that the British soldiers could do the same. The men were allowed a large daily ration of tea, 1 oz. per man—practically as much as they could drink; and, as I am now on this subject of bohea *versus* grog, I may as well state that the experiment was most successful. The men of no previous expedition have ever been called upon to perform harder or more continuous labor for over four months. . . . They were always cheery, and worked with a zealous will that could not be surpassed. This expedition would have been a bright era in our military annals had it no other result than that of proving the fallacy hitherto believed in of the necessity of providing our men when in the field with intoxicating liquors."

The writer in *Blackwood's Magazine* says:—

"The men were pictures of good health and soldier-like condition whilst stationed at Prince Arthur's Landing and the other larger camps. The men had fresh meat, bread, and potatoes every day. No spirits were allowed throughout the journey to Fort Garry, but all ranks had daily a large ration of tea. This was one of the very few military expeditions ever undertaken by English troops where intoxicating liquors formed no part of the daily ration. It was an experiment based upon the practice common in Canada, where the lumbermen, who spend the whole winter in the backwoods, employed upon the hardest labor, and exposed to a freezing temperature, are allowed no spirits, but have an unlimited quantity of tea. Our old-fashioned generals accept, without any attempt to question its truth, the traditional theory of rum being essential to keep the British soldier in health and humor. Let us hope that the experience we have

[1] Journal, United Service Institution, 1871, vol. xv., p. 74.
[2] January, 1871, p. 64.

acquired during the Red River expedition may have buried for ever this old-fogyish superstition. Never have the soldiers of any nation been called upon to perform more unceasingly hard work, and it may be confidently asserted without dread of contradiction, that no men have ever been more cheerful or better behaved in every respect. No spirit ration means no crime; and even the doctors who anticipated serious illness from the absence of liquor, will allow that no troops have ever been healthier than they were from the beginning to the end of the operation. With the exception of slight cases of diarrhœa, arising from change of diet, it may be said that sickness was unknown amongst us."

Sir Garnet Wolseley,[1] who commanded in this remarkable expedition, speaks very strongly against the rum ration, and says that, by substituting tea for rum, the health and efficiency of the men are increased, "their discipline will improve as their moral tone is raised, engendering a manly cheerfulness that spirit-drinking armies know nothing of."

In the Ashantee campaign of 1874 observations were carefully recorded by several officers.[2] The conclusions arrived at were—1. That abstinence did not render those who abstained more sickly as a whole or more liable to malarious fever; nor did it interfere with their powers of marching. 2. The issue of a ration of rum seemed to do good when given at the end of the day before going to rest. 3. That the quantity ($2\frac{1}{2}$ oz.) was amply sufficient. On the whole the necessity for the ration was by no means proved, although some officers returned rather shaken in their previous belief that alcohol was absolutely unnecessary in a military expedition.

In sieges, which are perhaps more trying to men than campaigning in the open field, the advantage of temperance has, on two occasions, been very marked. In the great siege of Gibraltar, Sir George Eliott, who was a teetotaller, enforced the most rigid temperance, and the long and arduous blockade was passed through with remarkably little sickness. At the siege of Jellalabad, in Afghanistan, the "illustrious garrison were quite destitute of all alcoholic liquors; and, to the astonishment of the officers, the Europeans never had been so healthy, cheerful, martial, and enduring and free from crime. During the Indian mutiny many regiments were debarred from spirits for a long time, and were much healthier than when they got them.

In fact, it may be confidently asserted that in war, spirits especially, and indeed all alcoholic liquors, are better avoided; and the phrase of an American army surgeon in the civil war, who noticed how great was the improvement when spirit prohibition was enforced, is fully justified by our own experience—"The curse of an army is intoxicating liquors; the spirit ration is the source of all this mischief."

When debarred from spirits and fermented liquids, men are not only better behaved, but are far more cheerful, are less irritable, and endure better the hardships and perils of war. The courage and endurance of a drunkard are always lessened; but in a degree far short of drunkenness, spirits lower, while temperance raises, the boldness and cheerfulness of spirit which a true soldier should possess.[3]

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[1] Soldiers' Pocket Book, 2d edition, p. 172.

[2] On the Issue of a Spirit Ration during the Ashantee Campaign of 1874 (Parkes).

[3] The custom of giving rations of spirits to soldiers and sailors (even now not altogether discontinued), was one of those incredible mistakes which are only made worse by the explanation that it was done to please the men, and cover neglect in other ways. If any one wishes to see what our army was in former days, and how dreadful military regulations made men drunkards in spite of themselves, they may refer to an old

Looking back to this evidence, it may be asked, Are there any circumstances of the soldier's life in which the issue of spirits is advisable, and if the question at any time lies between the issue of spirits and total abstinence, which is the best?

There seems but one answer. If spirits neither give strength to the body, nor sustain it against disease—are not protective against cold and wet, and aggravate rather than mitigate the effects of heat—if their use even in moderation increase crime, injure discipline, and impair hope and cheerfulness—if the severest trials of war have been not merely borne, but most easily borne, without them—if there is no evidence that they are protective against malaria or other diseases—then the medical officer will not be justified in sanctioning their issue under any circumstances.

The terrible system which in the East and West Indies made men drunkards in spite of themselves, and which by the issue of the morning dram did more than anything else to shatter the constitutions of the young soldiers, is now becoming a thing of the past. But the soldier is still permitted to get spirits too easily, and is too ignorant of their fatal influence on his health. Still the British army bears the unhappy character of the most intemperate army in Europe, and it is certain that its moments of misconduct and misfortune have been too frequently caused by the unrestrainable passion for drink. Remembering all these things, and how certainly it has been proved that drunkenness increases the spread of syphilis, it is not too much to say that the repression of this vice should be one of the chief duties of every officer in the army. Moderation should be encouraged by precept and example; wholesome beer and light wine should

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Peninsular surgeon's (William Fergusson's) Notes and Recollections of a Professional Life (1846). "During the last war" (he says, p. 74), "our sailors and soldiers appeared to live for the purpose of getting drunk; with them it seemed to be the chief article of their creed—the chief end of life. . . . 'Grog, grog,' was still the cry; I have seen it, as it were, forced down the throats of the innocent negro boy and the uncorrupted young recruit. We seemed to believe that the term *aqua vitæ* was its true designation. Every one was to have it; no matter what the age, the color, the country, or the breeding. Our Portuguese allies in the Peninsula were the soberest of mankind. They liked their own weak country wine to dilute their food, but that would not do for us. We actually sent for the rum of the West Indies and gave it them; and at the battle of Busaco, I saw a party of Portuguese artillery, as soon as the rum ration was served, as if they had been possessed by a devil (and they actually were possessed by a devil in the shape of alcohol), draw their swords and fight with one another, when actually under the fire of the enemy" (p. 85).

He cites numerous most lamentable facts, and well concludes that "our canteen system will in after-times be viewed with horror and astonishment, at its folly, corruption, and wickedness."

These opinions are not recalled without a motive. There is too much reason to fear that many officers still believe that soldiers must have spirits. Fergusson says that "the exceeding vulgarity of the prejudice that ardent spirits impart strength and vigor to the human frame is disgraceful to educated men;" and yet this belief is still actually held by persons in authority. Although in the army drinking is the great source of all crime and insubordination; although even within late years we have had one if not more instances that, even during an assault, men will sacrifice anything, even their honor, to obtain spirits; although the best officers know that this is the one point on which they cannot depend on their men, far too little has been done to make our army temperate. This does not mean that nothing has been done; on the contrary, in this, as in all things, progress has been made, but the measures are not sufficient to control an evil so gigantic. It is the same thing in civil life; there is no question that more disease is, directly and indirectly, produced by drunkenness than by any other cause, and that the moral as well as the physical evils proceeding from it are beyond all reckoning; and yet the attempts of the Legislature to set some bounds to intemperance have been and are opposed with a bitterness which could only be justified if the degradation and not the improvement of mankind was desired.

be invariably substituted for spirits, and if these cannot be procured, it may safely be said that the use of tea, coffee, or simple water is preferable to spirits under all circumstances of the soldier's life.

Resistance to Disease.—Malaria.—There are instances for and against the view that spirits are useful against malaria. On both sides the evidence is defective ; but there are so many cases in which persons have been attacked with malarious disease who took spirits, that it is impossible to consider the preventive powers great, even if they exist at all. On the other hand, when teetotallers have escaped malaria (as in the instance recorded by Drake),[1] there have been other circumstances, such as more abundant food and better lodging, which will explain their exemption. The probability is, that the reception and action of malaria are not influenced by the presence or absence of alcohol in the blood unless the amount of alcohol is so great as to lessen the amount of food taken.

Yellow Fever.—It is a general opinion in New Orleans and Mobile that the victims of yellow fever are chiefly those who drink freely (Drake). The old West Indian experience is to the same effect.

Cholera.—Intemperance, *per se,* has no influence, and teetotalism does not guard against cholera. When a regiment is attacked with cholera, and the men take to drinking, a number of pseudo-cases come into hospital of vomiting and cramps, which are often returned as cholera, but they seldom if ever pass into true cholera.

Dysentery.—It has been supposed, from some statistics for 1847, published in the *Fort George Gazette,* that teetotallers were more subject to dysentery, but the error was committed of not estimating sufficiently the influence of a particular station (Secunderabad), where it so happened a number of teetotallers were stationed during an outbreak of dysentery. The conditions of the station were to blame, not the habits of the men.

In none of the conditions now enumerated is there any evidence that alcohol is desirable.

Conclusion as to the Use of Alcohol.

The facts now stated make it difficult to avoid the conclusion that the dietetic value of alcohol has been much over-rated. It does not appear possible at present to condemn alcohol altogether as an article of diet in health ; or to prove that it is invariably hurtful, as some have attempted to do. It produces effects which are often useful in disease and sometimes desirable in health, but in health it is certainly not a necessity, and many persons are much better without it. As now used by mankind (at least in our own, and in many other countries), it is infinitely more powerful for evil than for good ; and though it can hardly be imagined that its dietetic use will cease in our time, yet a clearer view of its effects must surely lead to a lessening of the excessive use which now prevails. As a matter of public health, it is most important that the medical profession should throw its great influence into the scale of moderation ; should explain the limit of the useful power, and show how easily the line is passed which carries us from the region of safety into danger, when alcohol is taken as a common article of food.[2]

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[1] On the Interior Valley of North America.

[2] A great evil is growing up in India, which now could be checked, but which we shall be powerless to meet in a few years. The Hindoos, formerly the most temperate of races, are rapidly becoming addicted to drink. This is said to be partly owing to the regulations of the Government permitting, and even encouraging the sale of spirits,

Dietetic Use of Alcoholic Beverages.

In the previous remarks, the effect of alcohol only has been discussed, but beer and wine contain other substances besides alcohol.

In wine there are some albuminous substances, much sugar (in some wines), and other carbo-hydrates, and abundant salts. Whether it is that the amount of alcohol is small, or whether the alcohol be itself, in some way, different from that prepared by distillation,[1] or whether the coexistence of carbo-hydrates and of salts modifies its action, certain it is that the moderate use of wine, which is not too rich in alcohol, does not seem to lead to those profound alterations of the molecular constitution of organs which follow the use of spirits, even when not taken largely. Considering the large amounts of vegetable salts which most wines contain, it may reasonably be supposed that they play no unimportant part in giving dietetic value to wine. Indeed, it is quite certain that, in one point of view, they are most valuable; they are highly anti-scorbutic, and the arguments of Lind and Gillespie, for the introduction of red wine into the royal navy instead of spirits, have been completely justified in our own time by both French and English experience. It is now certain that with the same diet, but giving in one case red wine, in another rum, the persons on the latter system will become scorbutic long before those who take the wine. This is a most important fact, and in a campaign the issue of red wines should never be omitted. The ethers may also be important if, as indicated by Bernard, and recently pointed out by Dr. B. Forster,[2] they excite the flow of the pancreatic secretion, and thereby promote the absorption of fat.

In beer there appear to be four ingredients of importance, viz., the extractive matters and sugar, the bitter matters, the free acids, and the alcohol. The first, no doubt, are carbo-hydrates, and play the same part in the system as starch and sugar, appropriating the oxygen, and saving fat and albuminates from destruction. Hence, one cause of the tendency of persons who drink much beer to get fat. The bitter matters are supposed to be stomachic and tonic; though it may be questioned whether we have not gone too far in this direction, as many of the highest-priced beers contain now little else than alcohol and bitter extract. The action of the free acids is not known; but their amount is not inconsiderable; and they are mostly of the kind which form carbonates in the system, and which seem to play so useful a part. The salts, especially potassium and magnesium phosphates, are in large amount.

It is evident that in beer we have a beverage which can answer several purposes, viz., can give a supply of carbo-hydrates, of acid, of important salts, and of a bitter tonic (if such be needed) independent of its alcohol, but whether it is not a very expensive way of giving these substances is a question.

In moderation, it is no doubt well adapted to aid digestion, and to lessen to some extent the elimination of fat. It may be inferred that beer will cause an increase of weight of the body, by increasing the amount of

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although the alcoholic liquors form no part of the ordinary food of the people, and therefore their prohibition is not difficult; and partly from the bad example of the Europeans in India, who, as the dominant race, are impressing more and more the nations whom they control. It seems a matter which our statesmen may well look into, for it involves the happiness of many nations.

[1] Thudichum and Dupré could not, however, trace any difference between the alcohol in wines and that derived from other sources.

[2] Brit. Med. Journal, November, 1868.

food taken in, and by slightly lessening metamorphosis; and general experience confirms those inferences. When taken in excess, it seems to give rise to gouty affections more readily even than wine.

In spirits, alcohol is the main ingredient, chiefly in the form of ethyl-alcohol, though there are small amounts of propyl-, butyl-, and in some cases amyl-alcohols. In addition, there are sometimes small quantities of ether; and, in some cases, essential oils (as apparently in absinthe, and in one kind of Cape brandy), which have a powerful action on the nerves. But spirits are, for the most part, merely flavored alcohol, and do not contain the ingredients which give dietetic value to wine and beer. They are also more dangerous, because it is so easy to take them undiluted, and thus to increase the chance of damaging the structure and nutrition of the albuminous structures with which they come first in contact. There is every reason, therefore, to discourage the use of spirits, and to let beer and wines, with moderate alcoholic power, take their place.

SECTION II.

NON-ALCOHOLIC BEVERAGES.

Sub-Section I.—Coffee.

Unroasted coffee contains much cellulose (34 per cent.), fat (10 to 13 per cent.), sugar and dextrin, and vegetable acid (15.5), and legumin (10 per cent.). There is also a solid acid, aromatic oil in small quantities, caffein, and ash, the chief ingredients of which are potash and phosphoric acid. The total amount of caffein (free and combined), according to Payen, is about 1.736 per cent.; but this is more than other observers have found. In roasted coffee berries the average of Boutron and Robiquet's analyses gives .238 per cent. of caffein. Aubert[1] has given the amount as from .709 to .849 per cent., and Witte makes it .666 per cent.; Graham, Stenhouse, and Campbell state it as .87 per cent. It may be assumed to be .75 per cent. on an average. Aubert found that roasting coffee to any extent caused very little loss of caffein. The caffein is extracted easily by benzol or by chloroform.[2]

When coffee is roasted it swells, but becomes lighter (15 to even 25 per cent., if the coffee is dark roasted). The sugar is changed into caramel, the peculiar aroma is developed, the union between the caffein and the caffeo-tannic acid is broken up; several gases are formed, viz., carbon dioxide (in greatest amount), carbon monoxide, and nitrogen. It is owing to these gases that the roasted coffee swells so much.[3] In the infusion almost all the caffein is found, according to Aubert, while others say about one-half is lost. Aubert has found that in a cup of coffee made with 16.66 grammes, or .587 ounce avoirdupois (1 Prussian loth), there are

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[1] Archiv. für die ges. Phys., Band v., p. 589.

[2] Caffein and thein are the same substance. Theobromine belongs to the same series, and has apparently identical effects. In the leaves of the Paraguay tea (*Ilex paraguayensis*, the tea is called Mate in Paraguay), which are used to make tea in the Argentine confederation, and throughout the southern part of Brazil, there is also an alkaloid identical with thein. In dietetic properties, Paraguay tea is thought to stand between coffee and Chinese tea, but to be more like coffee. The alkaloid in guarana is also threin, according to Stenhouse.

[3] Coulier, Recueil de Mémoires de Méd. Mil., Juin, 1864, p. 508.

from .1 to .12 gramme (= 1.5 to 1.9 grain of caffein). In a cup of tea made from 5 to 6 grammes (= 77 to 92 grains) of tea, about the same amount of caffein is contained.

As an article of diet, coffee stimulates the nervous system, and in large doses produces tremors. Caffein given to animals augments reflex action, and may produce tetanus, or peculiar stiffness of muscles. It increases the frequency of the pulse in men, and removes the sensation of commencing fatigue during exercise. It has been said (J. Lehmann and others) to lessen the amount of urea and phosphoric acid, but this is doubtful.[1] It appears, however, to increase the urinary water. The pulmonary carbon dioxide is said to be increased (E. Smith). It increases the action of the skin.

In animals (frogs, dogs, and rabbits) caffein produced the following effects, as determined by Aubert and others :—Increased reflex action ; a peculiar stiffness of the muscles, sometimes tetanus ; no lessening of nervous excitability ; an invariable increase in pulse-frequency, and a lessening of the blood-pressure (in dogs). This effect on the circulation is peculiar and complex. Aubert is convinced that the work of the heart is less, in spite of the increased beats ; there is not time for perfect contraction, and this lessened power shows itself, he thinks, in the lessened blood-pressure. Aubert considers that the lessened heart-pressure is dependent on a more or less marked paralysis of the nerves passing to the heart from the ganglia ; the increased frequency must be dependent either on paralysis of the regulating or excitation of the contractive heart nerves, and of this alternative he adopts the latter. He thinks it uncertain whether coffee owes its dietetic value to the caffein.

Coffee is a most important article of diet for soldiers,[2] as not only is it invigorating, without producing subsequent collapse, but the hot infusion is almost equally serviceable against both cold and heat : in the one case, the warmth of the infusion, in the other, the action on the skin, being useful, while in both cases the nervous stimulation is very desirable. Dr. Hooker tells us that in the Antarctic expedition the men all preferred coffee to spirits, and this was the case in the Schleswig-Holstein war of 1849.

The experience of Algeria and India (where coffee is coming more and more into use) proves its use in hot climates.

It has been asserted to be protective against malaria. The evidence is not strong, but still is sufficient to authorize its use in malarious districts.

Making of Coffee.—Roasted and ground coffee must be served out to troops, as the delicate operation of roasting can never be performed by soldiers. Exposed to the air, the roasted and ground coffee loses its aroma in from two to four months ; but if packed in tins, it will keep it for several months. The tins should not be too large, so that no more

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[1] While Hoppe found a decrease in dogs, Voit found no alteration of urea ; and some very careful experiments, made by Dr. Squarey of University College, do not confirm Lehmann's observations on men so far as the urea is concerned. Dr. Squarey's experiments are far more complete than those of Lehmann ; the urea was not affected even by very large quantities of coffee. It would be interesting to examine the urine again after the use of the *Erythroxylon coca*. The late work of M. Moreno of Maiz (Paris, 1868) confirms the previous statements of the removal of the sensation of hunger by this substance. The cold infusion increases, he affirms, the arterial tension. Dr. Edmonstone Charles has lately called attention to its power of preventing thirst.

[2] The ration, one ounce, is generally too small, and might advantageously be doubled at least. See experiments recorded in The Issue of a Spirit Ration (Parkes), Appendix I., p. 39 et seq.

than necessary may be exposed to the air. It has been said that the tin is acted upon, but this does not appear to be the case for some time. The amount should be at least $\frac{6}{10}$ths of an ounce for each person per meal.

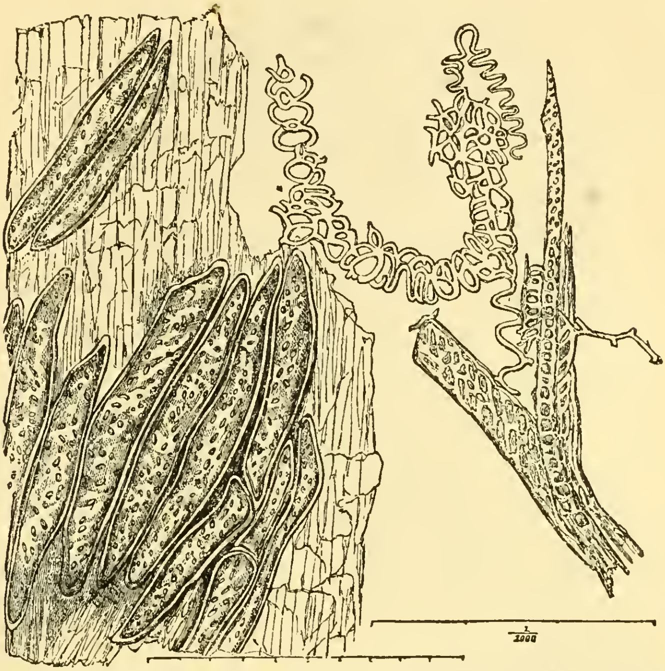

Fig. 56.—Testa of Raw Coffee, × 170; the right-hand figure shows the double spiral fibres in the raphe of the berry, × 500.

The coffee must not be boiled, or the aroma is in part dissipated; but if made with water of 180° or 200°, the coffee only gives up 19 to 25 per cent., whereas it ought to yield 30 to 35 per cent. In order to get the full benefit of the coffee, therefore, after the infusion has been poured off, the grounds should be well boiled in some more water, and the hot decoction poured over fresh coffee, so that it may take up aroma; the coffee thus partially exhausted can be used on the next occasion for boiling.

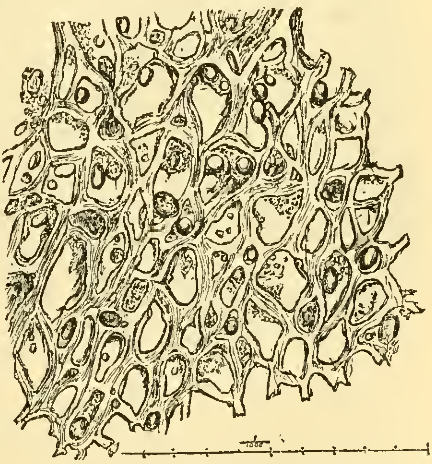

Fig. 57.—Raw Coffee berry; transverse section, × 170.

The infusion of coffee has a specific gravity of about 1008 to 1010; the oil, caffein, sugar, dextrin, and mineral matters are taken up by water.

Choice of Coffee.—This is determined entirely by the aroma and taste of the roasted coffee and of the infusion. If the coffee has been

damaged (as by sea-water, when the berries are washed in fresh water and redried), there is always a disagreeable taste even after roasting

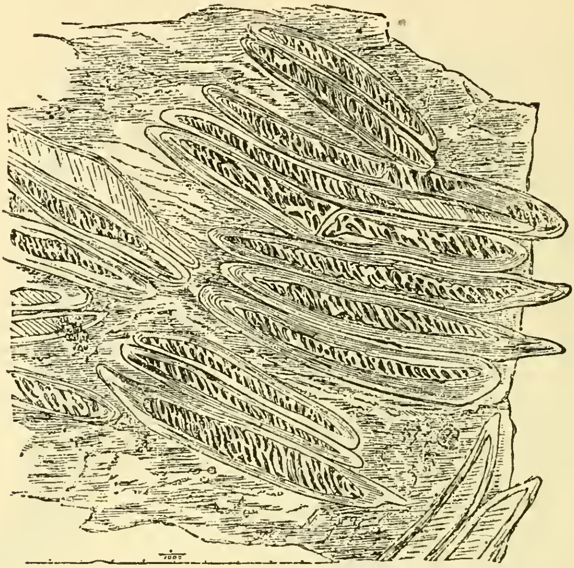

FIG. 58.—Roasted Coffee; the dark cells, containing air, show the spiral fibre.

(Chevallier). The berries give up less than usual to water (twelve per cent.).[1]

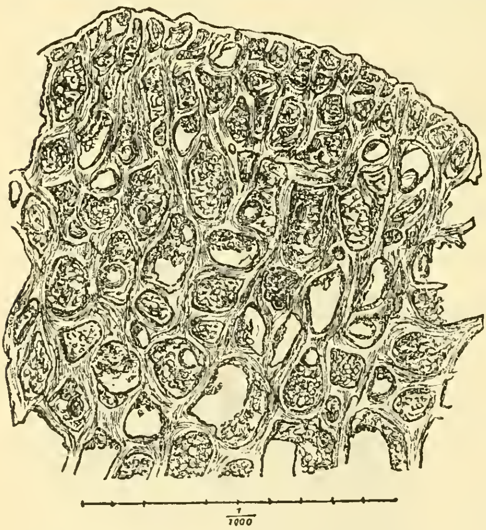

FIG. 59.—Roasted Coffee-berry: transverse section.

Adulterations.—The microscope detects adulterations with the greatest facility.

The structure of the coffee-berry is shown in the drawings.

The long cells of the testa (Figs. 56 and 58) are very marked. The interior of the berry also presents characters which are quite evident; an irregular areolar tissue contains light or dark yellow angular masses and oil globules, which are very different from any adulterations. The little corkscrew-like unrolled spiral fibres are chiefly found in the bottom of the raphe. The usual adultera-

[1] With regard to the choice of the coffee berry some caution must be used. The best coffee, that of Yeman, originally the Abyssinian berry, is a moderately large full berry (according to Palgrave), the inferior sorts being small and shrivelled. In India the same rule does not seem to hold good, and I have been told by officers of experi-

tions of coffee are roasted chiccory,[1] cereal grains or beans, potatoes, and sugar.

1. *Chiccory* is discovered by its smell ; by yielding a darker and denser infusion of a specific gravity of 1018 to 1020 ; and by its microscopic characters. It also sinks at once in water when roasted, whereas coffee floats for a long time, in consequence of the development of gas during roasting, or from the non-absorbent character of the perisperm and hard yellow granules of the cellulose. The microscopic test is the most important, and both the cells and dotted ducts of chiccory are quite characteristic, at least nothing like them exists in coffee.[2] The percentage of ash has been suggested as a means of detection. Coffee yields about 4 per cent., of which four-fifths are soluble in water : chiccory yields about 5 per cent., of which only one-third is soluble.

Chiccory contains a notable amount of sugar (12 to 14 per cent.), whereas coffee never has more than 1 per cent. Wanklyn has proposed to make this a basis of detection, using the standard copper solution.

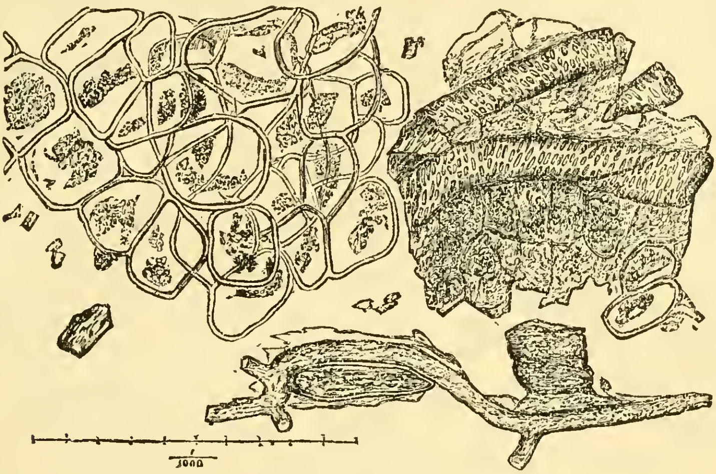

Fig. 60.—Chiccory Root; cells and dotted ducts.

2. Roasted *corn* or *beans* are at once known by the starch-grains, which frequently preserve the precise character of wheat or barley or beans. Iodine turns them at once blue. The infusion also gives a blue with iodine.

3. *Potato* starch is also at once detected ; there is nothing like it in coffee. *Sago* starch, which is sometimes used, is easily detected.

4. *Sugar* is detected by solution, and by the copper solution which it reduces, as the kind of sugar is almost always glucose. If caramel or burnt sugar be present, make an infusion, evaporate, dry, and taste ; if the ex-

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ence that in that country the best coffee is often a shrivelled and uninviting-looking article, whilst the fuller and apparently finer samples are really inferior for use as a beverage —(F. de C.)

[1] Chiccory is itself adulterated with roasted barley and wheat grain, acorns, mangold-wurzel, saw dust, and beans and peas.

[2] Various vegetable substances are now permitted to be sold as substitutes for coffee, provided they are properly labelled and made up in ¼ lb packets.

tract be brittle, dark colored, and bitter to the taste, caramel has been added (Hassall).

5. Pereira[1] has given a long list of adulterations of chiccory, and Hassall has also detected mixture with mangold-wurzel, parsnip, carrot, acorn, and saw-dust. The cells of mangold-wurzel are like chiccory, but much larger; those of carrot and parsnip are something like chiccory, but contain starch-cells; the starch-grains of the acorn are round or oval, with a deep culvert depression, or hilum. The infusion of chiccory is not turned blue by iodine; when incinerated the ash of chiccory should not be less than 5 per cent.

6. Recently *date-stones* ground have been mixed with coffee and chiccory, and sold as *date coffee.* They can be detected by the microscope, which shows numerous sclerogen cells.[2]

Sub-Section II.—Tea.

The chief kinds of black tea are Souchong, Congou, Oolong, and Pekoe. Bohea is not now found in the market. The chief green teas are Hyson, Hyson-stem, Twankay, Caper, and Gunpowder.

Dry tea contains about 1.8 per cent. of thein, 2.6 of albumen, 9.7 of dextrin, 22 of cellulose, 15 of tannin, 20 of extractives, 5.4 of ash, as well as other matters, such as oil, wax, and resin.

In some good teas the amount of thein is much greater. Péligot found as much as 6.21 per cent. in dry tea. The thein is combined with tannic acid.

Black tea contains from 6 to 10 per cent. of water—more often the latter quantity; green tea about 8 per cent.

The ash[3] consists principally of potash, soda, magnesia, phosphoric acid, chlorine, carbonic acid, iron, and silica.

There is rather more tannic acid, and more thein and ethereal oil, in green than black tea, and less cellulose: otherwise the composition is much the same (Mulder).

Black tea yields to boiling water..........	29–45	per cent.
As a mean......	38	"
Green	40–48	"
As a mean.....	43	"

About $\frac{6}{7}$ths of the soluble matters are taken up by the first infusion with hot water.[5]

If water contain much lime or iron, it will not make good tea; in each case the water should be well boiled with a little carbonate of soda for 15 or 20 minutes, and then poured on the leaves.

In the infusion are found dextrin, glucose, tannin, and thein. About 47 per cent. of the nitrogenous substances pass into the infusion, and 53

[1] Materia Medica, vol. ii., p. 1578 (1863).

[2] Analysis and Adulteration of Foods, by James Bell, 1881.

[3] The Society of Public Analysts have adopted 8 per cent. of ash as the maximum of perfectly dry tea. The amount in ordinary tea is about 5 to 6 per cent., of which about 3 per cent. is soluble. The ash of *spent* tea is only about 3 per cent., of which 0.5 is soluble.

[4] There appears now to be very little green tea in the market, since it has been decided that "facing" is an adulteration.

[5] The Society of Public Analysts have adopted 30 per cent. as the minimum extract in genuine tea; Wanklyn takes 32, and certainly good genuine tea yields this at least.

per cent. remain undissolved. If soda is added, a still greater amount is given to water.

The green tea (now little sold) is either natural, or colored (faced) with indigo, Prussian blue, clay, carbonate and acetate of copper, curcuma, gypsum, and chalk.

Scraping the tea-leaves and microscopic examination at once detect the shining blue particles of indigo and Prussian blue ; and the addition of an acid indicates which is indigo.[1] Copper is at once detected by solution in an acid and addition of ammonia. Letheby stated that black lead is used to give a bloom to black teas.

As an Article of Diet.—Tea seems to have a decidedly stimulative and restorative action on the nervous system, which is perhaps aided by the warmth of the infusion. No depression follows this. The pulse is a little quickened. The amount of pulmonary carbon dioxide is, according to E. Smith, increased.[2] The action of the skin is increased, that of the bowels lessened. The kidney excretion is little affected, perhaps the urea is a little lessened, but this is uncertain.[3]

As an article of diet for soldiers, tea is most useful. The hot infusion, like that of coffee, is potent both against heat and cold ; is most useful in great fatigue, especially in hot climates (Ranald Martin) ; and also has a great purifying effect on water. Tea is so light, is so easily carried, and the infusion is so readily made, that it should form the drink *par excellence* of the soldier on service. There is also a belief that it lessens the susceptibility to malaria, but the evidence on this point is imperfect.

Choice of Tea.—The tea should not be too much broken up, or mixed up with dirt. Spread out, the leaves should not be all large, thick, dark, and old, but some should be small and young. There will always be in the best tea a good deal of stalk and some remains of the flower. In old tea much of the ethereal oil evaporates, and the aroma is less marked.

The infusion should be fragrant to smell, not harsh and bitter to taste, and not too dark. The buyers of tea seem especially to depend on the smell and taste of the infusion.

Structure of the Tea Leaf.—The border is serrated nearly, but not quite to the stalk ; the primary veins run out from the midrib nearly to the border, and then turn in, so that a distinct space is left between them and the border. The leaf may vary in point of size and shape, being sometimes broader, and sometimes long and narrow. The appearance under the microscope of the upper and under surfaces is seen in the drawing. The border and the primary venation distinguish it from all leaves.[4] The leaves

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[1] The brick tea of the Tartars consist of old tea leaves, mixed with the leaves and stems of *Rhamnus theëzans*, *Rhododendron*, *Chrysanthemum*, *Rosa canina*, and other plants, mixed with ox's or sheep's blood. It is much used to purify water.

[2] Phil. Transactions, 1859.

[3] The evidence with respect to the urine is very contradictory ; but, on the whole, the action seems to be inconsiderable. Dr. Edward Smith considers that " tea promotes all vital actions, and increases the action of the skin." It is, perhaps, impossible at present to express its action in so succinct a form.

[4] The structure of the serrature is rather peculiar, showing an apparently abortive leaf-bud just within the point. This organ can be seen distinctly with an ordinary pocket lens, and consists of a cylindrical basal portion and a more or less cone-shaped apical part. From the reticulated body of the venation, a distinct little funiculus may be traced into each of the minute bud-like bodies which are situated just *within* the tip of the serrature. This latter particular is of importance, for, as might be expected, somewhat similar appendages may be found in other serrated leaves, but in all cases hitherto examined by us, they occur *at* instead of *within* the point of the serratures. No

which it is said have been mixed with or substituted for tea in this country are the willow, sloe, oak, Valonia oak, plane, beech, elm, poplar, hawthorn, and chestnut; and in China, *Chloranthus inconspicuus* and *Camellia Sasanqua* are said to be used. Of these the willow and the sloe are the only leaves which at all resemble tea leaves. The willow is more irregularly, and the sloe is much less perfectly and uniformly serrated.

To examine the leaves, make an infusion, and then spread out a number of leaves; if a leaf be placed on a glass slide, and covered with a thin glass, and then held up to the light, the border and venation can usually be well seen.

The leaves of the Valonia, if used, are at once detected by acicular crystal being found under the microscope.

Sometimes exhausted tea leaves are mixed with catechu or with a coarse powder of a reddish-brown color, consisting chiefly of powdered catechu,

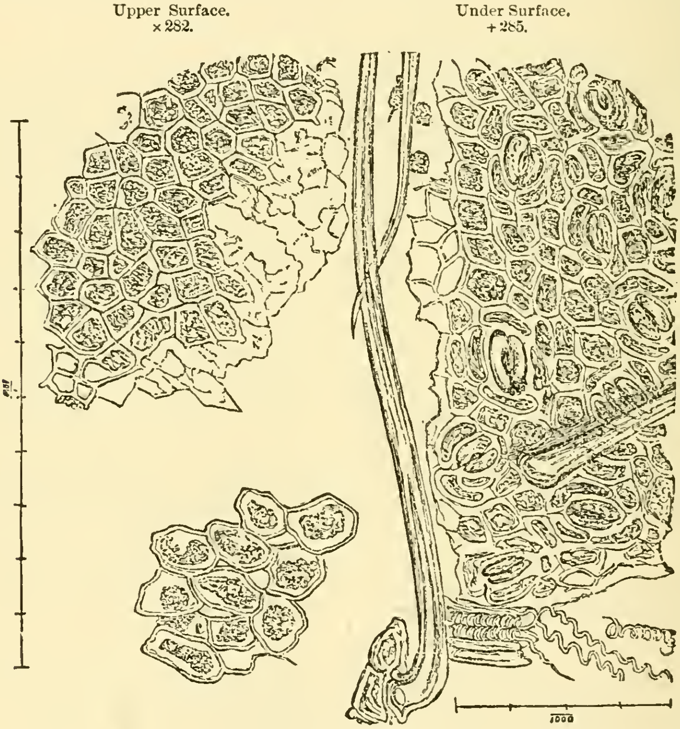


Fig. 61.—Dried Black Tea Leaf.

and called "La Veno Beno." Gum and starch are added, the leaves being steeped in a strong solution of gum, which, in drying, contracts them. The want of aroma, and the collection at the bottom of the infusion of powdered catechu, or the detection of particles of catechu, will at once indicate this falsification, which is, however, very uncommon. Sand and

notice appears to have been taken of this fact by structural botanists; but Dr. Macdonald, who first called attention to it, refers the bodies themselves to the category of marginal buds.—(F. de C.)

Plate VIII.—A.

Leaves and stalks of best Tea brought from China (1861) by private hand: natural size. Generally in Commercial Tea, the leaves are much larger and thicker, and often are cut transversely into two or three parts. Some stalks and remains of flowers are found in all Tea, even the best.

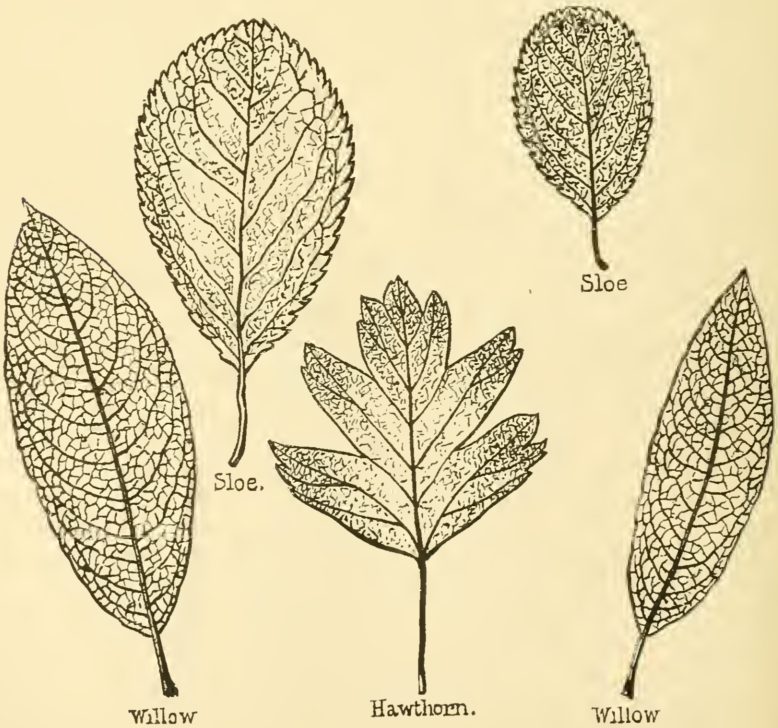
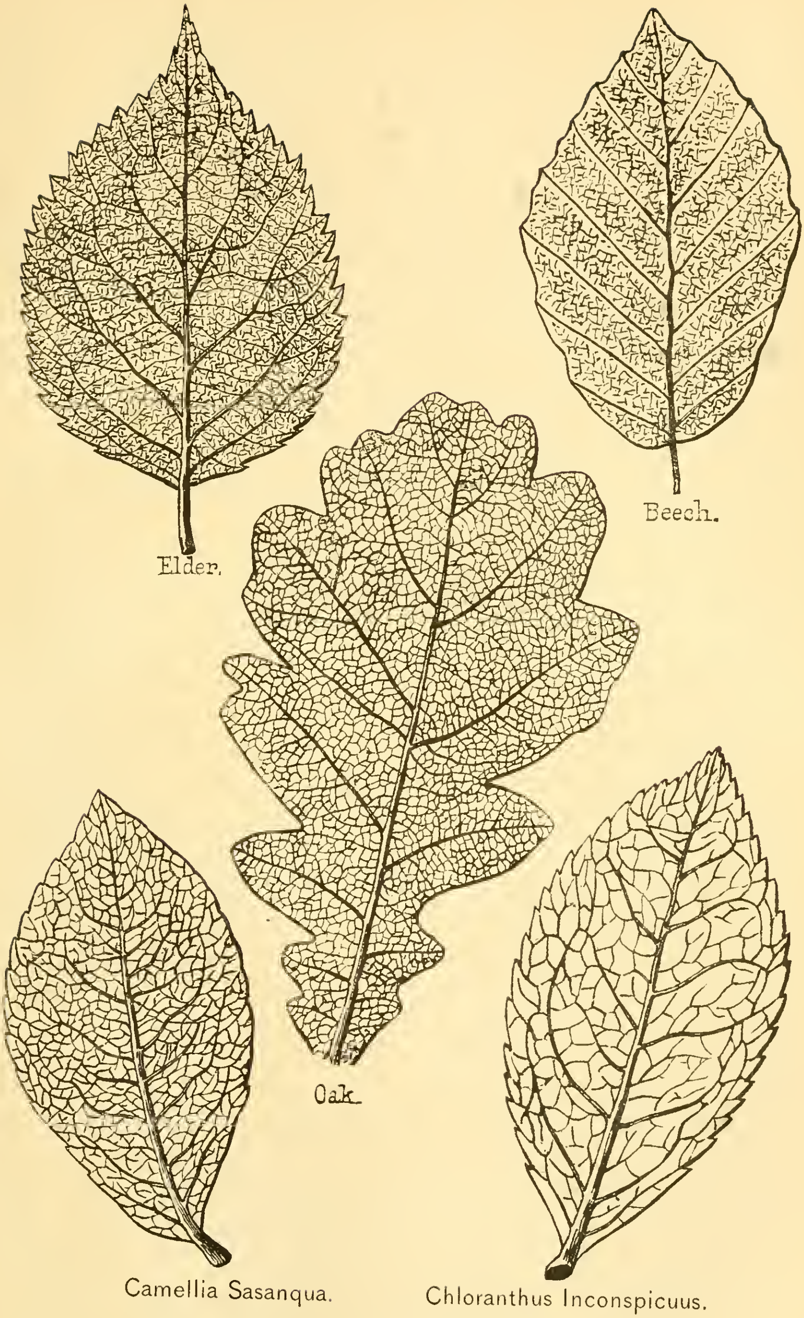


Plate VIII.—B.



LEAVES USED IN THE ADULTERATION OF TEA.

The Sloe, Willow, Oak, Beech, Elder, and Hawthorn have been nature-printed and then lithographed. The drawings of the Chloranthus Inconspicuus and the Camellia Sasanqua, which are said to be used by the Chinese, are copied from Hassall. The leaves of the Elm Poplar Plane are said to be sometimes used in England. Falsification with any kind of leaf is, however, now decidedly uncommon in this country.

magnetic oxide of iron are added by the Chinese. At first the latter was mistaken for iron filings, and when it was proved to be really magnetic oxide it was suggested that it came accidentally from the soil where the tea was cultivated. Hassall, however, gives good reasons for its being a wilful addition.[1]

Extraction of Thein.

Occasionally it may be desired to determine the quantity of thein. Take 10 grammes of tea, exhaust with boiling water, and add solution of subacetate of lead; filter; pass hydrosulphuric acid through to get rid of excess of lead; filter; evaporate to small bulk, and add a little ammonia; add more water, decolorize with animal charcoal, and evaporate slowly to small bulk. White feathery crystals of thein form, which should be collected on filtering paper, dried at a very low heat, and weighed.

Determination of Tannin.

Make an infusion and add solution of gelatine; collect precipitate, dry and weigh—100 = 40 of tannin (Marcet).

Examination of Tea.

Judge of the aroma of the dry tea and infusion; taste infusion; spread out leaves and see their characters; collect anything like mineral powder, and examine under microscope. The microscope will also show if the tea has deteriorated by keeping; sometimes *acari, fungi,* and *bacteria* may be found.

To make the infusion, take 10 grammes of tea, and infuse in 500 C.C. of *boiling* distilled or rain water.[2] Let it stand five or six minutes before smelling and testing it. Exhaust the leaves by boiling with successive portions of water, until no color is given up to the water. Measure the total amount of the infusion; take 100 C.C. and dry it in a water-bath,[3] and weigh. Calculate out the percentage.

Example.—The total quantity of the infusion from 10 grammes of tea was 1,890 C.C.; 100 C.C. taken and dried yielded 0.21 of extract; then $\frac{1890}{100} \times 0.21 = 3.969$ of extract in 10 grammes; this multiplied by $10 = 39.69$ per cent.

The exhausted leaves may also be dried and weighed, the loss representing the amount of extract, which ought to correspond with the amount obtained directly.

The ash should also be determined; 5 or 10 grammes are to be incinerated; the ash is generally gray, sometimes slightly greenish. Any excess

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[1] I have found minute quantities in two instances in tea supplied to Netley Hospital; in one the ash was 6.054 per cent.; in the other, 6.220. Hassall states that he has never found it except in tea that has been undoubtedly adulterated and yielded a very much greater amount of ash.—(F. de C.)

[2] The dealers usually take as much tea as is equal in weight to a new sixpence for the infusion. This is equal to about 3 grammes; it is dissolved in a cupful of water, about 5 ounces or 140 C.C.

[3] Mr. Wanklyn suggests a simple form of water-bath; an ordinary tin oil-can about three-parts full of water; this is boiled over a lamp, and the dish with infusion to be dried held over the narrow mouth in the ring of a retort stand. The drying is soon completed in the steam.

above 6 per cent. is suspicious ; if above 8 per cent. on the *perfectly dry tea*, adulteration is certain. About one-half of the ash is soluble in water ; the solution is often (but not always) pink, from the presence of manganese. The amount and character of the ash form good means of detecting the use of exhausted leaves.

The acidity of the infusion, and the amount of tannin and thein may also be determined ; as also the chlorine, alkalinity and iron of the ash. The best tests of the *quality* of the tea are the aroma and the physical characters.

Sub-Section III.—Cocoa.

Composition.—Although the theobromin of cocoa closely resembles thein and caffein, the composition of cocoa removes it widely from tea and coffee. The quantity of fat is large ; it varies even in the same sort of cocoa, but is usually from 45 to 49 per cent.[1] The theobromin is 1.2 to

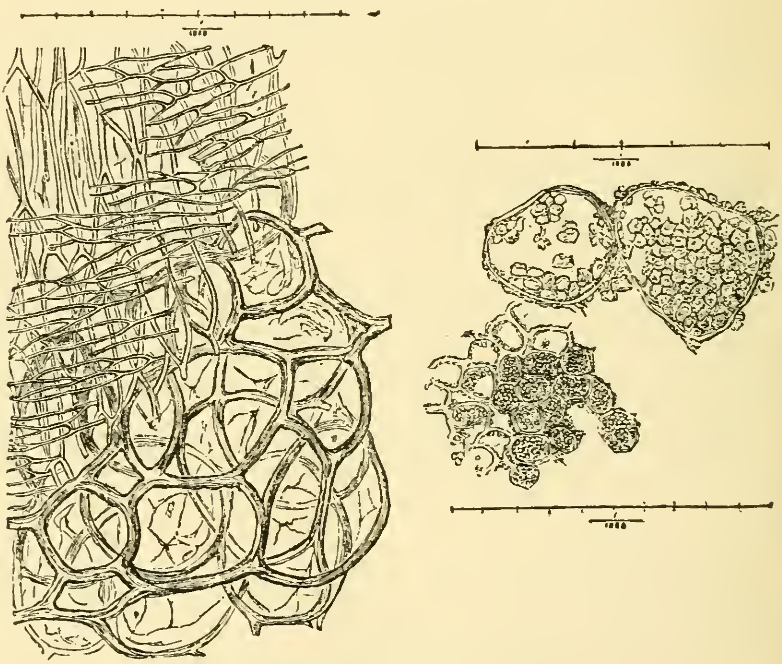

Fig. 62.—Cocoa, Outer Coat × 190.

1.5 per cent. ; the protein substances 13 to 18 per cent. The ash contains a large quantity of phosphate of potassium.

As an Article of Diet.—The large quantity of fat and albuminoid substance makes it a very nourishing article of diet ; and it is therefore useful in weak states of the system, and for healthy men under circumstances of great exertion. It has been even compared to milk. In South America

[1] The Society of Public Analysts have adopted 20 per cent. of cocoa butter as the minimum admissible.

cocoa and maize cakes are used by travellers ; and the large amount of agreeable nourishment in small bulk enables several days' supplies to be easily carried (Humboldt).

By roasting, the starch is changed into dextrin ; the amount of margaric acid increases, and an empyreumatic aromatic substance is formed.

The changes depend on the amount of roasting ; the lighter-colored nuts contain more unchanged fat, and less aroma ; the strongly roasted and dark cocoas have more aroma and bitterness.

Choice and Adulterations.—In commerce, cereal grains, starches, arrowroot, sago, or potato starch and sugar, are very commonly mixed with cocoa ; and some of the so-called homœopathic cocoas are rightly named, for the amount of cocoa is very small. Brick-dust and peroxide of iron are sometimes used (Normandy).[1] The structure of the cocoa is very marked.

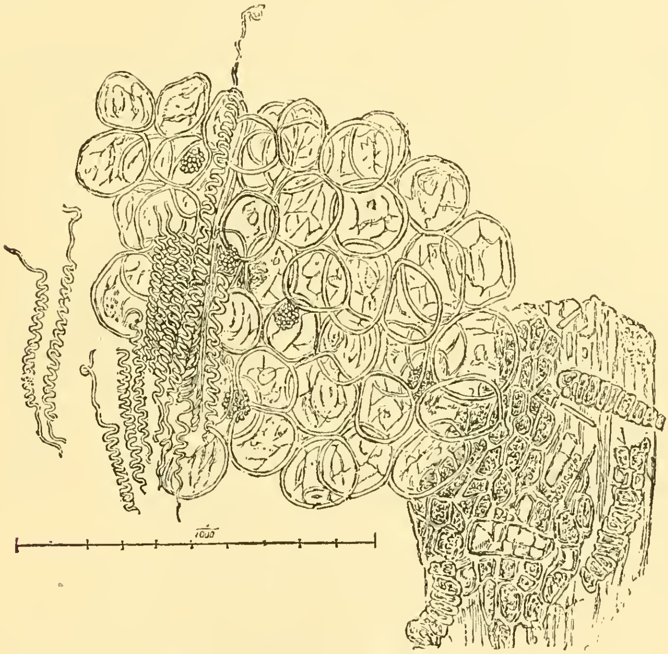

Fig 63.—Cocoa, Under Parts, Middle Coat × 190.

The starch-grains of cocoa are small, and embedded usually in the cells. The presence of starch-grains of cereals, arrowroot, sago, or other kinds of starch, is at once detected by the microscope. Sugar can be detected by the taste, and by solution. Mineral substances are best detected by incineration, digesting in an acid and testing for iron, lead, etc.

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[1] Hassall examined 54 samples ; 8 were genuine, 43 contained sugar, and 46 starch ; 39 out of 68 samples contained earthy coloring matter, as reddle, Venetian red, and umber.—*On Adulteration*, p. 166.

SECTION III.

CONDIMENTS.

SUB-SECTION I.—VINEGAR.

As an Article of Diet.—Robert Jackson was of opinion that the use of vinegar was too restricted in the army. This opinion he appears to have formed from considering the great use of vinegar made by the Romans. Whatever may have been the source of the opinion, there is no doubt of its correctness. Acetic acid plays that double part in the body which seems so important, of first an acid of a neutral salt, and then, in the form of carbonic acid, as the acid of an alkaline salt. But this valuable dietetic quality is partly counterbalanced in English vinegar by the unfortunate circumstance that sulphuric acid ($\frac{1}{1000}$th in weight) is allowed to be added to vinegar, and thus a strong acid is taken into the body, which is not only not useful in nutrition, but is hurtful from the tendency to form insoluble salts of lime. As the addition of sulphuric acid is not necessary,[1] and, indeed, is not permitted on the Continent, it is to be hoped the legislature will soon alter a system which has the effect only of injuring an important article of diet. The amount of vinegar which may be used may be from one to several ounces. On marches, the Romans mixed it with water as a beverage.

Examination of Vinegar.—Several kinds of vinegar are in the market, known by the Nos. 16, 18, 20, 22, and 24. Nos. 22 and 24 are the best, and contain about 5 per cent. of pure glacial acetic acid. The weakest kinds contain less than 3 per cent. The Society of Public Analysts have adopted 3 per cent. as the minimum admissible.

Quality.—1. Take specific gravity ; of the best, =1022 ; of the worst, = 1015. If below this, water has been added.

2. Determine acidity of 10 C.C. with the alkaline solution.[2] It is generally best to dilute the vinegar ten times with distilled water, and to take 10 C.C. of the diluted vinegar. Multiply the C.C. of alkaline solution used by 0.6, the result is acetic acid per cent.

Example.—10 C.C. of diluted vinegar took 8 C.C. of alkaline solution : $8 \times 0.6 = 4.8$ per cent. of acetic acid.

The acidity of English vinegar is chiefly caused by acetic and sulphuric acids, but it is usually calculated at once as glacial acetic acid. If it falls below 3 per cent.[3] water has probably been added. (The lowest noted by Hassall in 33 samples was 2.29.) If the specific gravity be low, and the acidity high, excess of sulphuric acid may have been added.

Sodium carbonate of ammonia gives a purplish precipitate in *wine* vinegar, but not in *malt* vinegar.

If excess of sulphuric acid be suspected, it must be determined by baryta ; this requires care, as sulphates may be introduced in the water. Hydrochloric acid and barium chloride are added ; the sulphate of barium collected, dried, weighed, and multiplied by .34305.

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[1] The absence of *Anguillula Aceti* has been by some attributed to the use of sulphuric acid. See Micrographic Dictionary, article "Anguillula." In a sample I examined, which swarmed with anguillulæ, there was only a trace of sulphuric acid.—(F. de C.)

[2] See Appendix A, Vol. II.

[3] Hassall says 3 5 per cent.

Adulterations.—Water; sulphuric acid in excess;[1] hydrochloric acid (uncommon); or common salt (detected by nitrate of silver and dilute nitric acid); pyroligneous acid (distil and re-distil the distillate, the residue will have the smell of pyroligneous acid); lead; copper from vessels (evaporate to dryness, incinerate, dissolve in weak nitric acid, divide into two parts, pass SH_2 through one, and test for copper in the other by ammonia, or by a piece of iron wire); corrosive sublimate (pass SH_2 through, collect precipitate); capsicum, pellitory, or other pungent substances (evaporate nearly to dryness, and dissolve in boiling alcohol, evaporate to syrup, taste; burnt sugar gives a bitter taste and a dark color to the syrup).

The presence of copper in the vinegar used for pickles may be easily detected by simply inserting the bright blade of a steel knife.

Sub-Section II.—Mustard.

Good mustard is known by the sharp acrid smell and taste. It is adulterated with turmeric (detected by microscope and liquor potassæ), wheat or barley starch (detected by microscope and iodine), and linseed (detected by microscope). Many samples of mustard are still mixed with

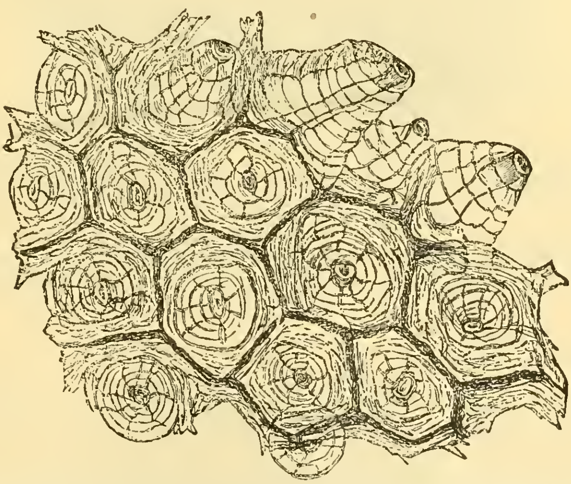

Fig. 64.—White Mustard Seed. Cuticle consisting of a perforated cellular epiderm and mucilage-cells, some by expansion escaping through the cuticular openings after being placed in water.

turmeric and starch of some kind, but this has very much lessened since the passing of the Adulteration Act. Clay and plaster-of-Paris are sometimes added, and cayenne is added to bring up the sharpness, if much flour is used.

The microscopic characters of mustard are well marked. The outer coat of the white mustard consists of a stratum of hexagonal cells, perforated in the centre, and other cells which occupy the centre portion of the

[1] The presence of sulphuric acid may be detected qualitatively, by adding a few drops of the vinegar to a piece of cane sugar, and evaporating on the water-bath. The solution becomes black in proportion to the mineral acid present.—*Hassall.*

hexagonal cells, and escape through the opening when swollen from imbibition of water; these cells are believed to contain the mucilage which is

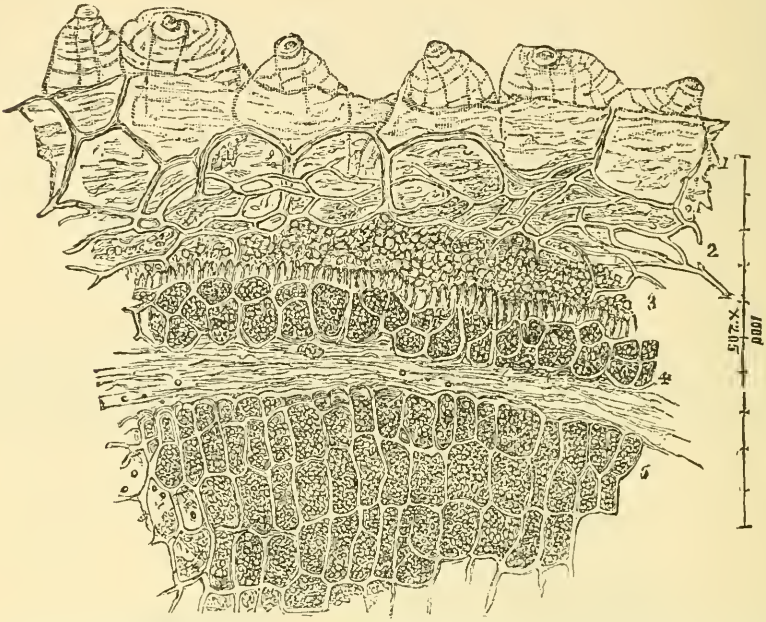

FIG. 65.—White Mustard Seed. 1. Outer coat, cuticle mucilage-cells. 2. Fibrous reticular. 3. Small angular cells. 4. Large cells and very delicate membrane. 5. Interior of seed with a few minute oil-globules,

obtained when mustard is placed in water. There are two internal coats made up of small angular cells; the structure of the seed consists of nu-

FIG. 66.—White Mustard Seed, central part, × 205.

merous cells containing oil, but no starch. The black mustard has the same characters, without the infundibuliform cells.

SUB-SECTION III.—PEPPER.

Pepper is adulterated with linseed, mustard husks, wheat and pea flour, rape cake, and ground rice. The microscope at once detects these adulterations.

The microscopic characters of pepper are rather complicated; there is a husk composed of four or five layers of cells and a central part. The cortex has externally elongated cells, placed vertically, and provided with

FIG. 67.—Section of Black Pepper Berry, central portion.

a central cavity, from which lines radiate toward the circumference; then come some strata of angular cells, which, toward the interior, are larger, and filled with oil. The third layer is composed of woody fibre and spiral cells. The fourth layer is made up of large cells, which toward the interior become smaller and of a deep red color; they contain most of the essential oil of the pepper. The central part of the berry is composed of large angular cells, about twice as long as broad. Steeped in water, some of those cells become yellow, others remain colorless. It has been supposed that the yellow cells contain piperine, as they give the same reactions as piperine does; the tint, namely, is deepened by alcohol and nitric acid, and sulphuric acid applied to a dry section causes a reddish hue (Hassall).

White pepper is the central part of the seed, but some small particles of cortex are usually mixed with it. It is composed of cells containing very small starch-grains. Hassall says that the central white cells are so hard they may be mistaken for particles of sand. A little care would avoid this. The starch-grains are easily detected, however small, by iodine.

Pepper dust is merely the sweepings of the warehouses. Rape or linseed cake, cayenne and mustard husks, are mixed with pepper dust, and it is then sold as pepper.

Fig. 68.—Transverse Section of Black Pepper Berry.

Sub-Section IV.—Salt.

The goodness of salt is known by its whiteness, fine crystalline character, dryness, complete and clear solution in water. The coarser kinds, containing often chloride of magnesium, and perhaps lime salts, are darker colored, more or less deliquescent, and either not thoroughly crystallized or in too large crystals.

SECTION IV.

LEMON AND LIME JUICE.

These juices contain free acids in large quantities, chiefly citric, and a little malic acid, sugar, vegetable albumen, and mucus.

The expressed juice of the ripe fruit of the *Citrus Limonum*, as ordered by the British Pharmacopœia, is said to have a specific gravity of 1.039,

and to contain on an average 32.5 grains of citric acid in one fluid ounce.[1] The fresh juice of the lime (*Citrus Limetta*, or *Citrus acida*) has a rather less specific gravity (1.037), and contains less acid (32.22 grains per ounce).[2]

The very important Merchant Shipping Act,[3] which regulates the issue of lemon juice on board merchant vessels, does not define the strength; but it has been stated by Mr. Stoddart,[4] that the Board of Trade standard is a specific gravity of 1030 without spirit, and 30 grains of citric acid per ounce. It occasionally is as high as 1050.

As found in commerce, for merchant shipping, or used in the Royal Navy, the lime or lemon juice is chiefly prepared in Sicily or the West Indies; it is mixed with spirit (usually brandy or whiskey, which gives it a slightly greenish-yellow hue), and olive oil is poured on the top.

Sugar is added to it when issued, to make it more agreeable to taste, in the proportion of half its weight. Lemon juice is usually issued in bottles containing three to four pints, not quite filled, and is covered with a layer of olive oil. About 1 ounce of brandy is added to each 10 ounces of juice. Sometimes the juice is boiled, and no brandy is added; the former kind keeps best (Armstrong). Both are equal in anti-scorbutic power (Armstrong). Good lemon juice will keep for some years, at least three years (Armstrong); bad juice soon becomes turbid, and then stringy and mucilaginous, and the citric and malic acids decompose, glucose and carbon dioxide being formed. Some turbidity and precipitate do not, however, destroy its powers.

As found in the market, it is frequently mixed with water, and sometimes with other acids. In 20 samples examined in 1868 by Mr. Stoddart, 7 were genuine, 5 were watered, and 8 were artificial; tartaric acid being present in one, and sulphuric acid in another sample.[5]

In the examination the points which seem of consequence, in addition to the determination of the free acidity, are the fragrancy of the extract and the alkalinity of the ash, proving the existence of some alkaline citrate. The latter could, however, be imitated, but the fragrancy cannot be so.

Examination of Lemon Juice.

1. Pour into a glass, and mark physical characters; turbidity, precipitate, stringiness, etc. The taste should be pleasant, acid, but not bitter. Add lime water, and boil; if free citric acid is present, a large precipitate of calcium citrate is formed, which redissolves as the solution cools. Evaporate very carefully to extract, to test the fragrancy, etc.

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[1] Mr. Stoddart (Pharm. Jour., October, 1868) points out that the specific gravity is too high for the quantity of acid stated; there may, however, be other ingredients. He gives himself the specific gravity as 1.040 to 1.045, and the citric acid as 39 to 46 grains per ounce (citric acid $C_6H_8O_7$). Mr. Stoddart mentioned that when lemons are kept the citric acid decomposes, and glucose and carbon dioxide arise. But yet citric acid is made from damaged fruit.

[2] Stoddart, op. cit., p 205.

[3] The Merchant Shipping Act, 1867.

[4] Pharm. Jour., October, 1868, p. 204.

[5] The lime juice used in the Arctic Expedition, 1875–76, gave on analysis 27 grains of citric per ounce as issued, that is, after being fortified with about 15 per cent. of proof-spirit. Before fortifying it contained 32 grains. (See analyses by Professor Attfield and Mr. Bell, Report of Committee on Scurvy, pages xliii. and li.). Samples analyzed at Netley showed a specific gravity of 1023 as issued, and 1035.7 after driving off the alcohol; the extract was about 8½ per cent. The unfortified juice froze at 25° F., the fortified remained liquid down to 15° F. Prolonged freezing at a temperature of nearly 0° F. produced no change in the character or amount of the constituents.

2. Take the specific gravity, remembering that spirit is present; then, if necessary, evaporate to one-half to drive off alcohol, dilute to former amount, and take specific gravity at 60° Fahr.

3. Determine acidity by alkaline solution.[1] Express the acidity as citric acid ($C_6H_8O_7$); 1 C.C. of the alkaline solution = 6.4 milligrammes of citric acid. As the acidity is considerable, the best way is to take 10 C.C of the juice, add 90 C.C. of water, and take 10 C.C. of the dilute fluid, which will give the acidity of 1 C.C. of the undiluted juice. If the number of C.C. used for the diluted juice is multiplied by 2.8 it gives the acidity in grains per ounce.

4. Test for adulteration, viz:—

(*a*) *Tartaric Acid.*—Dilute and filter, if the lime juice be turbid; add a little solution of acetate of potash; stir well, without touching the sides of the glass, and leave for twenty-four hours; if tartaric acid be present the potassium tartrate will fall.

(*b*) *Sulphuric Acid.*—Add barium chloride after filtration, if necessary; if any precipitate falls, add a little water and a few drops of dilute hydrochloric acid to dissolve the barium citrate, which sometimes causes a turbidity.

(*c*) *Hydrochloric Acid.*—Test with silver nitrate and a few drops of dilute nitric acid.

(*d*) *Nitric Acid.*—This is an uncommon adulteration; the iron or brucine test can be used as in the case of water.

Factitious Lemon Juice.

It is not easy to distinguish well-made factitious lemon juice; about 552 grains of crystallized citric acid are dissolved in a wine pint of water, which is flavored with essence of lemon dissolved in spirits. This corresponds to about 19 or 20 grains of dry citric acid per ounce. The flavor is not, however, like that of the real juice, and the taste is sharper. Evaporation detects the falsification.

Use of Lemon Juice.

In military transports, the daily issue of one ounce of lemon juice per head is commenced when the troops have been ten days at sea, and by the Merchant Shipping Act (1867) the same rule is ordered, except when the ship is in harbor, and fresh vegetables can be procured. It is mixed with sugar.

If dried vegetables can be procured, half the amount of juice will perhaps do.

In campaigns, when vegetables are deficient, the same rules should be enforced. On many foreign stations, where dysentery takes a scorbutic type (as formerly in Jamaica, and even of late years in China), lemon juice should be regularly issued.

Substitutes for Lemon Juice.

Citric acid is the best, or citrate of potassium; then perhaps vinegar, though this is inferior, and lowest of all is nitrate of potassium.[2] The tar-

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[1] See Appendix A, Vol. II.

[2] On this point see Bryson's paper in the Medical Times and Gazette, 1850. Reference may also be made to a review on scurvy, which Dr. Parkes contributed to the British and Foreign Medico-Chirurgical Review, in October, 1848, for evidence on the point.

trates, lactates, and acetates of the alkalies may all be used, but there are no good experiments on their relative antiscorbutic powers on record. If milk is procurable, it may be allowed to become acid, and the acid then neutralized with an alkali. The fresh juices of many plants, especially species of cacti, can be used, the plant being crushed and steeped in water; and in case neither vegetables, lemon juice, nor any of the substitutes can be procured, we ought not to omit the trial of such plants of this kind as may be obtainable.

CHAPTER VIII.

SOILS.

TOPOGRAPHICAL REPORTS AND CHOICE OF SITES.

THE term soil is used here in a large sense, to express all the portion of the crust of the earth which by any property or condition can affect health. The subdivision into surface soil and subsoil is often very useful; and these terms need no definition.

SECTION I.

CONDITION OF SOIL AFFECTING HEALTH.

Soil consists of mineral, vegetable, and often animal substances, in the interstices of which are also air and often water.

In reviewing the conditions which affect health, it will be convenient to commence with the air and the water in soils.

SUB-SECTION I.—THE AIR IN THE SOIL.

The hardest rocks alone are perfectly free from air; the greater number even of dense rocks, and all the softer rocks, and the loose soils covering them, contain air. The amount is in loose sands often 40 or 50 per cent.; in soft sandstones, 20 to 40 per cent. The loose soil turned up in agricultural operations may contain as much as 2 to 10 times its own volume of air.

The nature of the air in soils has been examined by a good many observers; it is mostly very rich in carbon dioxide, is very moist, and probably contains effluvia and organic substances, derived from the animal or vegetable constituents, but which have not been properly examined. Occasionally it contains carburetted hydrogen, and in most soils, when the water contains sulphates, a little hydrogen sulphide may be found. It has been examined by Nichols[1] in America, Fleck[2] in Dresden, Fodor[3] in Buda-Pesth, Lewis and Cunningham[4] in Calcutta, and many others. Nichols made his experiments in the Back-bay lands of Boston, Massachusetts, land made by throwing gravel upon sea mud. His first series of experiments was upon air drawn from depths of $3\frac{3}{4}$ to $5\frac{1}{2}$ feet. There was no hydrogen sulphide, and only a little ammonia; the CO_2 was from 1.49 to 2.26 volumes per 1,000, and varied inversely as the height of the ground-

[1] Sixth Report of the Board of Health, Massachusetts, 1875.

[2] 4ter and 5ter Jahresbericht der Chemischen Centralstelle, Dresden, 1876.

[3] Deutsche Vierteljahrschrift für öffentliche Gesundheit., Band vii., p. 205, 1875; also Hygienische Untersuchungen ueber Luft, Boden und Wasser, von Dr. Josef Fodor, Braunschweig, 1882.

[4] The Soil in its Relation to Disease, Calcutta, 1875.

water, which was very near the surface. This relation, however, was not constant at a depth of 6 to 10 feet. Fleck found at 2 metres the CO_2 29.9 per 1,000, and the oxygen 163.3; at 6 metres, the CO_2 79.6, and the oxygen 148.5. Fodor found (out of 13 observations) at 1 metre from 8.99 to 10.39 of CO_2, and oxygen from 187.97 to 213.35; at 4 metres (11 observations) from 26.31 to 54.45 CO_2, and oxygen from 179.06 to 185.32. The great amount of CO_2 points to very intense chemical changes in the ground, especially in the deep strata, but at the same time it may be very variable in different places. The amount of oxygen was in a measure inversely as the CO_2. At a depth of 4 metres (13 feet) the air would be irrespirable, and would extinguish a light. (How many cellars go as deep as 13 feet into the ground, and the cellar air feeds the house with air!) From the examination of the organic matter, he comes to the conclusion that it is not necessarily its oxidation on the spot that produces the CO_2, and that therefore the latter cannot be taken, except under certain conditions, as a measure of impurity, depending as it does to a large extent upon the *permeability* of the soil.[1] He found no hydrogen sulphide, but a good deal of nitric acid and ammonia, the relative quantities depending upon free access of air or otherwise. As regards moisture, the mean percentage of humidity was 80.7 at 2 metres and 93.8 at 4. Lewis and Cunningham, in their observations at Calcutta, found results somewhat similar to those of Fodor, the CO_2 being greatest at the lower strata examined. The composition of soil air differs at different times and seasons, the absolute and relative amounts of the constituents varying under varying conditions.

The amount of air in soils can be roughly estimated, in the case of rather loose rocks, by seeing how much water a given bulk will absorb, which can be done by the following plan:—Weigh a piece of dry rock, and call its weight W: then weigh it in water and call this weight W_1: then take it out of the water saturated with moisture, and weigh it again: call this weight W_2. We then have—

$$\frac{(W_2 - W)100}{W - W_1} = \text{percentage of air.}$$

When the soil is loose, Pettenkofer adopts the following plan:—Dry the loose soil at 212° Fahr. (100° Cent.), and powder it, but without crushing it very much; put it into a burette, and tap it so as to expel the air from the interstices as far as possible; connect another burette by means of an elastic tube with the bottom of the first burette and clamp it on; pour water into No. 2 burette, and then, by pressing the clamp, allow the water to rise through the soil until a thin layer of water is seen above it; then read off the amount of water thus gone out of the second burette. The calculation—

$$\frac{\text{Amount of water used} \times 100}{\text{Cubic centimetres of dry soil}} = \text{percentage of air.}^{2}$$

[1] Fodor attempts to distinguish (but hardly successfully) between *porosity* and *permeability*.

[2] Renk's plan is very simple. Take a measured quantity of soil, say 50 C.C., shaken well together, so as to represent its natural condition as much as possible, and put it into a 200 C.C. graduated glass measure: then pour in 100 C.C. of water, and shake well so as to expel all air. Allow it to stand a little, and read off the point at which the water stands. Suppose it stands at 125 C.C., then the 50 C.C. of soil and the 100 C.C. of water, when shaken together, only occupy a space of 125 C.C., the difference, 25 C.C., representing the bulk of air displaced from the 50 C.Cs. of soil: therefore $\frac{25}{50} \times 100 = 50$ per cent. of air or porosity in the sample of soil.

The subterranean atmosphere thus existing in many loose soils and rocks is in continual movement, especially when the soils are dry; the chief causes of movement are the diurnal changes of heat in the soil, and the fall of rain, which must rapidly displace the air from the superficial layers, and at a later date, by raising the level of the ground water, will slowly throw out large quantities of air from the soil. Fodor considers the temperature of the air, the ground temperature, the action of the winds, rainfall, barometric pressure, and level of ground water to be all influential in causing movement of the ground air, and consequent relative change in its constituents. As far as the CO_2 was concerned, Lewis and Cunningham found that the air temperature and wind were both inoperative, whilst the moisture had the greatest influence on the upper strata, and the ground-water on the lower.

Local conditions must also influence the movement; a house artificially warmed must be continually fed with air from the ground below, and doubtless this air may be drawn from great depths. Coal gas escaping from pipes, and prevented from exuding by frozen earth on the surface, has been known to pass sideways for some distance into houses.[1] The air of cesspools and of porous or broken drains will thus pass into houses, and the examination of drains alone often fails to detect the cause of effluvia in the house.

The unhealthiness of houses built on "made soils," for some time after the soils are laid down, is no doubt to be attributed to the constant ascent of impure air from the impure soil into the warm houses above.

To hinder the ascent of air from below into a house is therefore a sanitary point of importance, and should be accomplished by paving and concreting the basement, or, in some cases, by raising the house on arches off the ground. The improvement of the health of towns, after they are well paved, may partly be owing to lessening of effluvia, though partly also to the greater ease of removing surface impurities. In some malarious districts great benefit has been obtained by covering the ground with grass, and thus hindering the ascent of the miasm.

As a rule, it is considered that loose porous soils are healthy, because they are dry, and, with the qualification that the soil shall not furnish noxious effluvia from animal or vegetable impregnation, the rule appears to be correct. It is, however, undoubted that dry and apparently tolerably pure soils are sometimes malarious, and this arises either from the soils being really impure, or from their porosity allowing the transference of air from considerable distances. Even on the purest soils it is desirable to observe the rule of cutting off the subsoil air from ascent into houses.

The diseases which have been attributed to telluric effluvia are—

Paroxysmal fevers.	Bilious remittent fever.
Enteric (typhoid) fever.	Cholera.
Yellow fever.	Dysentery.

The questions connected with these effluvia will be noticed farther on.

The Water in the Soil.

The water present in soils is divided into moisture and ground water. When air as well as water is present in the interstices, the soil is merely moist. The ground water must be defined, with Pettenkofer, as that condition in which all the interstices are filled with water, so that, except in

[1] Lancet, 1873, vol. ii., p. 592.

so far as its particles are separated by solid portions of soil, there is a continuous sheet of water. Other definitions of ground water have been given, but it is in this sense it is spoken of here.

Moisture of Soil.—The amount of moisture depends on the power of the soil to absorb and retain water, and on the supply of water to the soil either from rain or ground water. With respect to the first point, almost all soils will take up water. Pfaff[1] has shown that dried quartz sand on a filter can take up as much as 20 per cent. of water, and though in the natural condition in the soil the absorption would not be so great, there is no doubt that even the hardest sands retain much moisture. After several months of long-continued drought, Mr. Church found a light calcareous clay loam subsoil to contain from 19 to 28 per cent. of water.

A loose sand may hold 2 gallons of water in a cubic foot, and ordinary sandstone may hold 1 gallon. Chalk takes 13 to 17 per cent.; clay, if not very dense, 20; humus, as much as 40 to 60, and retains it strongly. The so-called "cotton soil" of Central India, which is derived from trap rock, absorbs and retains water with great tenacity; the driest granite and marbles will contain from .4 to 4 per cent. of water, or about a pint in each cubic yard.

The moisture in the soil is derived partly from rain, to which no soil is absolutely impermeable, as even granite, clay slate, and hard limestone may absorb a little. Practically, however, soils may be divided into the impermeable (unweathered granite, trap and metamorphic rocks, clay slate, dense clays, hard oolite, hard limestone and dolomite, etc.) and permeable (chalk sand, sandstone, vegetable soils, etc.). The amount of rain passing into the soil is influenced, however, by other circumstances—by the declivity and inclination of the soil; by the amount of evaporation, which is increased in summer; by hot winds; and by the rapidity of the fall of rain, which may be greater than the soil can absorb. On an average, in this country, about 25 per cent. of the rain penetrates into the sand rock, 42 per cent. into the chalk, and from 60 to 96 per cent. into the loose sands. The rest evaporates or runs off the surface by the lines of natural drainage. The rapidity with which the rain water sinks through soil evidently varies with circumstances; in the rather dense chalks it has been supposed to move 3 feet downward every year, but in the sand its movement must be much quicker.

The moisture of the soil is not, however, derived solely from the rain; the ground water, by its own movement of rising and falling, and evaporation from the surface of the subterranean water-sheet, and capillary attraction, makes the upper layers of the soil wet. By these several agencies the ground near the surface is in most parts of the world kept more or less damp.

Determination of Moisture in the Soil.—By drying 10 grammes at a temperature of 220° Fahr. (104.4° Cent.), then weighing, exposing to air, and observing the increase of weight, an idea is formed of the amount of moisture, and of the hygrometric properties of the soil. If the dried soil is put over water under a bell jar, it will be exposed to air saturated with moisture, or by observing the dry and wet bulb thermometers, the humidity of the air at the time can be noted.

The Ground or Subsoil Water.—The subterranean sheet of water is at very different depths below the surface in different soils; sometimes it is only 2 or 3 feet from the surface, in other cases as many hundreds. This

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[1] Zeitsch. für Biologie, Band iv., p. 249.

depends on the compactness or permeability of the soil, the ease or difficulty of outflow, and the existence or not of an impermeable stratum near or far from the surface. The underground sheet of water is not necessarily horizontal, and in some places it may be brought nearer to the surface than others by peculiarities of ground. The water is in constant movement, in most cases flowing toward the nearest watercourses or the sea; the rate of movement has not yet been perfectly determined. In Munich, Pettenkofer reckons its rate as 15 feet daily; the high water in the Elbe moves the ground water in the vicinity at the rate of about 7 or 8 feet daily. Fodor[1] gives the mean rate at Buda-Pesth as 53 metres (174 feet), with a maximum of 66 metres (216 feet) in twenty-four hours, reckoning by the rise of the wells following the rise of the Danube.

The rate of movement is not influenced solely by compactness or porosity of soil, or inclination. The roots of trees exert a great influence in lessening the flow; and, on the other hand, water runs off more rapidly than before in a district cleared of trees. The level of the ground water is constantly changing. It rises or falls more or less rapidly, and at different rates in different places; in some cases its movement is only a few inches either way, but in most cases the limits between its highest and lowest levels in the year are several feet (in Munich about 10). In India the changes are greater. At Saugor, in Central India, the extremes of the soil water are from a few inches from surface (in the rains) to 17 feet in May. At Jubbulpore it is from 2 feet from the surface to 12 or 15.

The *causes of change* in the level of the ground water are the rainfall, pressure of water from rivers or the sea, and alterations in outfall, either increased obstruction or the reverse. The effect of the rainfall is sometimes only traceable weeks or even months after the fall, and occasionally, as in plains at the foot of hills, the level of the ground water may be raised by rainfalls occurring at great distances. The pressure of the water in the Rhine has been shown to affect the water in a well 1,670 feet away. The pressure of the Danube at Buda-Pesth is found to influence a well at a distance of 2,700 feet (Fodor).

In a place near the Hamble River (Hampshire) the tide was found to affect the water of a well at a distance of 2,240 feet; the well itself being 83 feet deep and 140 feet above mean water-level.[2]

Diseases connected with Moisture and Ground Water.—Dampness of soil may presumably affect health in two ways—1st, by the effect of the water, *per se*, causing a cold soil, a misty air, and a tendency in persons living on such a soil to catarrhs and rheumatism; and 2d, by aiding the evolution of organic emanations. The decomposition which goes on in a soil is owing to four factors, viz., presence of decomposable organic matters (animal or vegetable), heat, air, and moisture. These emanations are at present known only by their effects; they may be mere chemical agencies, but there is increasing reason to believe that they are low forms of life which grow and propagate in these conditions. At any rate, moisture appears to be an essential element in their production. The ground water is presumed to affect health by rendering the soil above it moist, either by evaporation or capillary attraction, or by alternate wettings and dryings.

A moist soil is cold, and is generally believed to predispose to rheumatism, catarrh, and neuralgia. It is a matter of general experience that most persons feel healthier on a dry soil.

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[1] Op. cit., Bd. ii., p. 98.

[2] Lectures on State Medicine, by F. de Chaumont (Smith & Elder), p. 91, 1875.

In some way which is not clear, a moist soil produces an unfavorable effect on the lungs: at least in a number of English towns, which have been sewered, and in which the ground has been rendered much drier, Buchanan has shown that there has been a diminution in the number of deaths from "phthisis."[1] Dr. Bowditch of Boston (U.S.), and Dr. Middleton of Salisbury, noticed the same fact some years ago. Buchanan's evidence is very strong as to the fact of the connection, but the nature of the link between the two conditions of drying of soil and lessening of certain pulmonary diseases is unknown. It is curious how counter the observation runs to the old and erroneous view, that in malarious (and therefore wet) places there is less phthisis.

A moist soil influences greatly the development of the agent, whatever it may be, which causes the paroxysmal fevers. The factors which must be present to produce this agent are heat of soil (which must reach a certain point = isotherm of 65° Fahr. of summer air temperature), air, moisture, and some impurity of soil, which in all probability is of vegetable nature. The rise and fall of the ground water, by supplying the requisite degree of moisture, or, on the contrary, by making soil too moist or too dry, evidently plays a large part in producing or controlling periodical outbreaks of paroxysmal fevers in the so-called malarious countries. The development of malaria may be connected either with rise or with fall of the ground water. An impeded outflow which raises the level of the ground water has, in malarious soils, been productive of immense spread of paroxysmal fevers. In the making of the Ganges and Jumna Canals, the outflow of a large tract of country was impeded, and the course and extent of the obstruction was traced by Dempster and Taylor by the almost universal prevalence of paroxysmal fevers and enlarged spleens in the inhabitants along the banks.[2] The severe and fatal fever which has prevailed in Burdwan, in Lower Bengal, for a number of years past, appears to be in part owing to the obstruction to the natural drainage from mills and from blockage of watercourses.[3] In some cases relative obstruction comes into play; *i.e.*, an outfall sufficient for comparatively dry weather is quite inadequate for the rainy season, and the ground water rises. At Pola, in Istria, for example, there are no marshes, but in the summer sometimes half, sometimes 90 per cent. of all cases are malarious; the reason is, that a dense clay lies a little below an alluvial soil, and the only exit for the rain is through two valley-troughs, which cannot carry off the water fast enough in the wet season,[4] from February to May.

A remarkable instance of excessive rainfall, causing an outbreak of malarial disease, occurred at Kurrachee, in Scinde, in 1869. The average

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[1] Buchanan: Ninth and Tenth Reports of the Medical Officer to the Privy Council, 1866, p. 48, and 1867, p. 57. As the term "phthisis" is a general one, and includes all the fatal diseases of the lungs, with destruction of lung-tissue (tuberculous and inflammatory), as well as other cases of wasting, with pulmonary symptoms, it would be well to translate the word "phthisis" by the phrase "wasting diseases of the lungs."

[2] The observations of Dempster and Taylor on the Jumna Canal have been more recently confirmed by Ferguson (Sanitary Administration of the Punjab for 1871, Appendix IV.), who has investigated the effect on malarious disease on the Bári Doáb Canal District; he found canal irrigation increased malarious fever, and apparently by raising the soil-water levels.

[3] Dr. Derby (Third Report of the State Board of Health of Massachusetts, Boston, 1872) points out how ague has been produced by obstructions to outflow, such as tide-mills, etc. So long ago as 1828, authority to remove a dam was obtained on account of injury to health. See also case recorded by Dr. Cattell in Natal, Army Medical Reports, vol. xiii., 1871, p. 178, produced by natural causes.

[4] Dr. Jilck, in Archiv der Heilk., 1870, p. 493.

annual rainfall in Scinde in 11 years (1856–66) was only 6.75 inches; and the greatest rainfall in that time was 13.9 inches (1863). In 1867 the rainfall was 2.73, in 1868 it was 3.36 inches; while in 1869 it reached the unprecedented amount of 28.45 inches, of which 13.18 fell in July and 8.39 inches in September. April, May, October, November, and December were rainless. The 1st Batt. 21st Regiment had the following attacks of paroxysmal fever per 1,000 of strength:—In April, none; in May, 9; in June, 39; in July, 30; in August, 93; in September, 105; in October, 198; in November, 1,004; and in December, 644. In December the regiment was embarked for Madras, as it had "thoroughly lost heart." The disease was not fatal, as the death-rate for the year, from all causes, was only 25.7 per 1,000. At Kurrachee, as the rainfall is usually so small, the ground dries fast, and is then non-malarious. The ground is flat, and there is no subsoil drainage. In 1866, when there was heavy rainfall (13.75 inches), there was also a development of malarial disease, which was continued in 1867.

The opposite result, viz., an increased outflow lowering the subsoil water, has been observed in drainage operations, and very malarious places have been rendered quite healthy by this measure, as in Lincolnshire, and many parts of England. The case of Boufaric, in Algeria, is a good instance; successive races of soldiers and colonists had died off, and the station had the worst reputation. Deep drainage was resorted to; the level of the ground water was lowered less than 2 feet. This measure, and a better supply of drinking-water, have reduced the mortality to one-third.

A case mentioned by Pettenkofer[1] is also very striking as to the effect of subsoil drainage on some kind of fever in horses. Two royal stables near Munich, with the same arrangements as to stalls, food, and attendance, and the same class of horses, suffered very unequally from fever; horses sent from the unhealthy to the healthy stables did not communicate the disease. The difference between the two places was, that in the healthy stables the ground water was 5 to 6 feet, in the unhealthy only 2½ feet from the surface. Draining the latter stables, and reducing the ground water to the same height, made these stables as healthy as the others.

Typhoid (enteric) fever has also been supposed to be connected with changes in moisture of the soil, owing to rising and falling of the ground water. Professor Pettenkofer's observations on the wells of Munich led Buhl to the discovery that in that city there is a very close relation between the height of the ground water and the fatal cases of typhoid;[2] the outbreaks of typhoid fever occurred when the ground water was lowest, and especially when, after having risen to an unusual height, it had rapidly fallen. Pettenkofer has repeated and extended the inquiry with the same results. The point has been also numerically investigated by Seidel[3] in Munich and Leipzig for the years 1856–64 and 1865–73, and from a mathematical consideration of the numbers he concludes that, according to the theory of probabilities, it is 36,000 to 1 that there is, in each period, a connection between the two occurrences.[4] Other observations in

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[1] Quoted by Kirchner, Lehrb. der Mil.-Hygiene, 1869, pp. 217, 218.
[2] Zeitschrift für Biologie, Band i., p. 1.
[3] Ibid., Band i., p. 221, and Band ii., p. 145.
[4] Ranke, however, points out that no typhoid exists in the neighborhood of Munich, but what is imported from Munich, although soil and ground water are the same. Munich has a soil consisting of fine sand, with a peculiar power of holding nitrogenous substances; it is provided with cesspools, from which more than 90 per cent. of the

Germany are confirmatory,[1] but in this country the connection has not been traced. In some outbreaks of enteric fever, the ground water has been rising and not falling. Fodor[2] says that at Buda-Pesth the rise of enteric fever mortality accompanies the rising ground water, and the two fall together. In other instances the attacks have been traced to impure drinking-water or milk, to sewer emanations, or to personal contagion, and the agency of the ground water has appeared to be quite negative. Dr. Buchanan[3] has quoted a case, in which the sinking of the ground water and the outbreak of fever were coincident, and yet the connection was, so to speak, accidental, for the efficient cause of the outbreak was the poisoning of the drinking-water with typhoid evacuations. And he also points out that when the ground water has actually been lowered in certain English towns by drainage operations, typhoid fever has not increased as it should do, according to theory, but has diminished, owing to the introduction of pure water from a distance. He thus thinks that, while a connection between the prevalence of typhoid fever and sinking of the ground water must be admitted to exist, it is indirect, and the true cause of the fever is impurity of the drinking-water. Pettenkofer has replied to this view,[4] and denies, from actual analysis, the fact of the contamination of the drinking-water in typhoid outbreaks.

At the present moment the observations of Pettenkofer, and the case of the barracks at Neustift, recorded by Buxbaum, are certainly in favor of the opinion that a direct connection may exist in some cases between the sinking of the ground water and outbreaks of typhoid; but the frequency and extent of the connection remains to be determined, and in this country, at any rate, the other conditions of spread of typhoid appear to be far more common.

Assuming the truth of the connection, the other conditions which Pettenkofer considers necessary, besides a rapid sinking of ground water after an unusual rise, are impurity of the soil from animal impregnation, heat of soil, and the entrance of a specific germ.[5]

A very similar view is held by Pettenkofer in respect of cholera, and he has advanced many striking arguments[6] to show that while sporadic cases

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contents soak into the surrounding soil, and, as the streets are well paved, the houses are the only outlets for the foul soil-air.

Virchow, in his Report on the Sewerage of Berlin, shows that the mortality is greatest in July and August, the curve corresponding accurately with the variation of the ground water, the death-rate being greatest at the lowest level; this is chiefly due to deaths under one year. At the lowest level there is every year a little epidemic of typhoid. At Zürich in 1872 the results were directly opposed to Pettenkofer's views (see Lectures on State Medicine, p. 101). Geissler considers the influence of the rise and fall of the ground water a local matter, and agrees with Rudolph Rath in attributing the typhoid of Berlin to contaminated water. The case of water transmission (which he quotes from Hägler) in the village of Lausen is a very conclusive one. (Schmidt's Jahrbüch., 1874, No. 2, 185; also Archiv für Klin. Medicin, 1873, p. 237; see also an abstract in the Report on Hygiene, Army Med. Reports, vol. xv., p. 197.)

Vogt of Bern (Trinkwasser oder Bodengase) strongly supports Pettenkofer's views, and considers the propagat on by drinking-water as illusory.

[1] Buxbaum, "Der Typhus in der Kaserne zu Neustift," Zeitsch. für Biologie, Band vi., p. 1. This seems strong evidence in favor of Pettenkofer's view.

[2] Op. cit.

[3] Medical Times and Gazette, March, 1870.

[4] Ibid., June, 1870; and Vierteljahrschrift für offentliche Gesundheitspflege, 1870, Band ii., pp. 176, 197.

[5] Vierteljahrschrift für offentl. Ges., Band ii., p. 181.

[6] Among his many essays, special reference may be made to his Analysis of the "Reasons of the Immunity of Lyons from Cholera," Zeitsch. für Biol., Band iv., p. 400.

of cholera may occur, that there will be no wide-spread epidemic, unless certain conditions of soil are present, viz., an impure porous soil, which has recently been rendered moist by a rise of ground water, and then has been penetrated by air during the fall of ground water, and into which the specific germ (*Keim*) of cholera has found its way.[1]

In Germany Pettenkofer's views on the spread of cholera have not met with universal acceptance,[2] though there are several instances in support. In India the weight of the evidence is at present against Pettenkofer's views;[3] but as investigations are now going on which will in a few years settle the point, it is desirable at present to refrain from forming a decided opinion, except in so far that we may feel sure that the singularly localized outbreaks which sometimes occur in India are quite unconnected with any subsoil-water variations.

In the report of MM. Lewis and Cunningham (op. cit.) it is shown that the cholera at Calcutta in 1873–74 followed the curve of the ground water-level inversely, exactly in accordance with Pettenkofer's views.

Dysentery and the so-called bilious remittent fevers, which occur in foul camps and on the ground largely contaminated by animal impurities, may be conjectured to be also influenced by variations in the ground water, but satisfactory evidence has not yet been given. In the Calcutta Report, above cited, the maximum of fever corresponded with the maximum of CO_2 in the soil atmosphere, and with the highest ground water-level. Dysentery, on the other hand, showed two maxima, one at the rise of the water-level, and the other at the corresponding point of the fall.

Fodor[4] states that at Buda-Pesth cholera, enteritis, and intermittent fever appear to be connected with the processes which go on in the upper layer of the soil, and cholera mortality rises and falls inversely with the ground water-level, according to Pettenkofer's view. Enteric fever, on the other hand, appears to be connected with the processes which go on in the lowest stratum of the soil, its mortality varying directly with the ground water-level. The lowest lying parts of the city have the most impure soil, and are specially subject to cholera, enteritis, and typhoid fever; whilst measles, scarlet fever, croup, and diphtheria appear to invade all parts of the city indifferently.

Measurement of the Ground Water.—The height at which water stands in wells is considered to give the best indication of the height of the ground water. Professor Pettenkofer uses a rod on which are fixed a number of little cups, and when let down into the well and drawn up again, the uppermost cup which contains water, marks, of course, the height of the water; the length of the cord or rod used for letting down the cups being

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[1] It is, of course, to be understood that the impurity which aids in producing cholera is derived from persons ill with the disease. For a discussion on Pettenkofer's views on this point, see Report on Hygiene for 1872, in the Army Med. Department Report, vol. xiii. (1873); and for his latest views, vol. xxii. (1882), pp. 251 et seq.

[2] A careful analysis of this subject is contained in F. Küchenmeister's work (Verbreitung der Cholera, 1872), and the work by F. Sander (Unters über die Cholera, 1872). Dr. Frank (health officer of Munich) believes that the cholera in 1873–74 was imported from Vienna, and points out that in 1873 the ground water and death-rate were not in accordance with Pettenkofer's theory. (See Report on Hygiene, Army Med. Report, vol. xv., p. 203).

[3] Townsend's Reports on the Cholera in Central India contain so many cases where ground water could have had no influence, that it appears impossible to accept Pettenkofer's theory. In Dr. Cornish's Report for 1871 are some good observations on subsoil water, which if carried out in the same way for a few years will decide this question.

[4] Op. cit.

known, the changing level of the well can be estimated to within half an inch. Some precautions are necessary in making these observations ; if a rope is used, it may stretch with use, or in a hot dry wind, or contract in wet weather, and thereby make the observation incorrect ; local conditions of wells, proximity to rivers, etc., must be learnt, else what may be termed local alterations in a well may be wrongly supposed to mean changes in the general level of the ground water. It is necessary, therefore, to make the observations simultaneously in many wells and over a considerable district. The observations should be made not less often than once a fortnight, and oftener if possible, and be carried on for a considerable time before any conclusions are drawn.

Pettenkofer also uses a large float which is suspended by a chain travelling over a pulley : this supports an indicator at its other end, which marks the height on a fixed scale.

Method of rendering Soil Drier.—There are two plans of doing this,—deep drainage and opening the outflow. The laying down of sewers often carries off water by leaving spaces along the course of the sewers, but this is a bad plan ; it is much better to have special drains for ground water laid by the side of or under the sewers. Deep soil drainage (the drains being from 8 to 12 feet deep and 10 to 20 feet apart) is useful in all soils except the most impermeable, and in the tropics should be carried out even on what are apparently dry sandy plains.

In some cases soil may be rendered drier by opening the outflow. This is an engineering problem which physicians can only suggest. The clearing of watercourses, removal of obstructions, and formation of fresh channels, are measures which may have an effect over very large areas which could not be reached by ordinary drainage.

Sub-Section II.—Solid Constituents of the Soil.

There are certain general features which can be conveniently considered first.

1. *Conformation and Elevation.*—The relative amounts of hill and plain ; the elevation of the hills ; their direction ; the angle of slope ; the kind, size, and depth of valleys ; the chief water-sheds, and the direction and discharge of the watercourses ; the amount of fall of plains, are the chief points to be considered.

Among the hills, the unhealthy spots are enclosed valleys, punch-bowls, any spot where the air must stagnate ; ravines, or places at the head or entrance of ravines.

In the tropics especially ravines and nullahs are to be avoided, as they are often filled with decaying vegetation, and currents of air frequently traverse them. During the heat of the day the current of air is up the ravine ; at night down it. As the hills cool more rapidly than the surrounding plains, the latter current is especially dangerous, as the air is at once impure and cold. The worst ravine is a long narrow valley, contracted at its outlet, so as to dam up the water behind it. A saddleback is usually healthy, if not too much exposed ; so are positions near the top of a slope. One of the most difficult points to determine in hilly regions is the probable direction of winds ; they are often deflected from their course, or the rapid cooling of the hills at night produces alteration.

On plains the most dangerous points are generally at the foot of hills, especially in the tropics, where the water, stored up in the hills, and flowing to the plain, causes an exuberant vegetation at the border of the hills.

A plain at the foot of hills may be healthy, if a deep ravine cuts off completely the drainage of the hill behind it.

The next most dangerous spots are depressions below the level of the plain, and into which therefore there is drainage. Even gravelly soils may be damp from this cause, the water rising rapidly through the loose soil from the pressure of higher levels.

Elevation acts chiefly by its effect in lessening the pressure of the air, and in increasing the rapidity of evaporation. It has a powerful effect on marshes; high elevations lessening the amount of malaria, partly from the rapid evaporation, partly from the greater production of cold at night. Yet malarious marshes may occur at great elevations, even 6,000 feet (Erzeroum and Mexico).

2. *Vegetation.*—The effect of vegetation on ground is very important. In cold climates the sun's rays are obstructed, and evaporation from the ground is slow; the ground is therefore cold and moist, and the removal of wood renders the climate milder and drier. The extent to which trees impede the passage of water through the soil is considerable.

In hot countries vegetation shades the ground, and makes it cooler. The evaporation from the surface is lessened; but the evaporation from the vegetation is so great as to produce a perceptible lowering effect on the temperature of a place. Pettenkofer has calculated that an oak tree which had 711,592 leaves, had during the summer months (May–October) an evaporation equal to 539.1 centimetres (= 212 inches), while the rainfall was only 65 centimetres (= 25.6 inches); so that the evaporation was $8\frac{1}{3}$ times the rainfall; this shows how much water was abstracted from the soil, and how the air must have been moistened and cooled. Observations in Algeria (Gimbert) have shown that the *Eucalyptus globulus* absorbs and evaporates 11 times the rainfall, extremely malarious places being rendered healthy in this way in four or five years.

The hottest and driest places in the tropics are those divested of trees.[1]

Vegetation produces also a great effect on the movement of air. Its velocity is checked; and sometimes in thick clusters of trees or underwood the air is almost stagnant. If moist and decaying vegetation be a coincident condition of such stagnation, the most fatal forms of malarious disease are produced.

Vegetation may thus do harm by obstructing the movement of air; on the other hand, it may guard from the currents of impure air. The protective influence of a belt of trees against malaria is most striking.

In a hygienic point of view, vegetation must be divided into herbage, brushwood, and trees; and these should be severally commented on in reports.

Herbage is always healthy. In the tropics it cools the ground, both by obstructing the sun's rays, and by aiding evaporation; and nothing is more desirable than to cover, if it be possible, the hot sandy plains of the tropics with close-cut grass.

Brushwood is frequently bad, and should often be removed. There is, however, evidence that the removal of brushwood from a marsh has increased the evolution of malaria, and that, like trees, brushwood may sometimes

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[1] It has been proposed (by Mr. Milne Home) to plant trees at Malta, with the view of improving and regulating the water-supply.

Mr. Robert L. Stevenson has considered the thermal influence of forests, in a paper in the Proceedings of the Royal Society of Edinburgh (May 19, 1873). Single trees act as bad conductors; the air of forests is generally cooler than free air, and certainly cooler than cleared lands; forests heat the air during the day and chill it at night.

offer obstruction to the passage of malaria. It must also be remembered that its removal will sometimes, on account of the disturbance of the ground, increase malarious disease for the time; and therefore, in the case of a temporary camp in a hot malarious country, it is often desirable to avoid disturbing it. When removed, the work should be carried on in the heat of the day, *i.e.*, not in the early morning or in the evening.

Trees should be removed with judgment. In cold countries they shelter from cold winds; in hot, they cool the ground; in both, they may protect from malarious currents. A decided and pernicious interference with the movement of air should be almost the only reason for removing them. In some of the hottest countries of the world, as in Southern Burmah, the inhabitants place their houses under the trees with the best effects; and it was a rule with the Romans to encamp their men under trees in all hot countries.

The kind of vegetation, except as being indicative of a damp or dry soil, does not appear to be of importance.

Absorption of Heat.—The heat of the sun is absorbed in different amounts by different soils equally shielded or unshielded by vegetation. The color of the soil and its aggregation seem chiefly to determine it. The dark, loose, incoherent sands are the hottest; even in temperate climates Arago found the temperature of sand on the surface to be 122° Fahr., and at the Cape of Good Hope Herschel observed it to be no less than 159°.[1] The heating power of the sun's rays is indeed excessive. In India, the thermometer placed on the ground and exposed to the sun will mark 160° (Buist), while 2 feet from the ground it will only mark 120°. Buist thinks that if protected from currents of air it would mark 212° when placed on the ground. The absorbing and radiating powers of soil are not necessarily equal, though they may be so. Generally the radiating power is more rapid than the absorbing; soils cool more rapidly than they heat. Some of the marshes in Mexico cool so rapidly at night that the evolution of malaria is stopped, and the marsh is not dangerous during the night. A thermometer marked 32° Fahr. on the ground, while 16 feet above the ground it marked 50° Fahr. (Jourdanet).

In Calcutta, Lewis and Cunningham[2] found that the temperature of the soil varied with the season. In hot weather the thermometer stood highest in the air, next highest in the upper stratum of the soil, and lowest in the lower stratum. In cold weather the conditions were exactly reversed, the air being coolest and the lowest stratum of soil the hottest. During rain, however, these relations were not constant.

With regard to absorbing power, the following table by Schübler contains the only good experiments at present known:—

Power of retaining Heat; 100 being assumed as the Standard.

Sand with some lime	100.0	Clayey earth	68.4
Pure sand	95.6	Pure clay	66.7
Light clay	76.9	Fine chalk	61.8
Gypsum	72.2	Humus	49.0
Heavy clay	71.11		

The great absorbing power of the sands is thus evident, and the comparative coldness of the clays and humus. Herbage lessens greatly the ab-

[1] Meteorology, p. 4.

[2] Op. cit.

sorbing power of the soil, and radiation is more rapid. On the Orinoco, a naked granite rock has been known to have a temperature of 118° Fahr., while an adjacent rock, covered with grass, had a temperature 32° lower.

In cold countries, therefore, the clayey soils are cold, and as they are also damp, they favor the production of rheumatism and catarrhs; the sands are, therefore, the healthiest soils in this respect. In hot countries the sands are objectionable from their heat, unless they can be covered with grass. They sometimes radiate heat slowly, and therefore the air is hot over them day and night.

The sun's rays cause two currents of heat in soil: one wave diurnal, the heat passing down in temperate climates to about 4 feet in depth during the day, and receding during the night—the depth, however, varying with the nature of the soil, and with the season; the other wave is annual, and in temperate climates the wave of summer heat reaches from 50 to 100 feet. The line of uniform yearly temperature is from 57 to 99 feet below the surface (Forbes).

Not only does the amount of radiation differ in different soils, but a change is produced in the heat by the kind of soil. The remarkable researches of Tyndall have shown, that the heat radiated from granite passes through aqueous vapor much more readily than the heat radiated by water (though the passage is much more obstructed than in dry air). In other words, the luminous heat rays of the sun pass freely through aqueous vapors, and fall on water and granite; but the absorption produces a change in the heat, so that it issues again from water and granite changed in quality; it will be most important for physicians if other soils are found to produce analogous changes.

With regard to the effect of temperature of the soil on disease, it can hardly be doubted that it powerfully influences malaria, and probably also aids the progress of cholera.

Reflection of Light.—This is a matter of color; the white glaring soils reflect light, and such soils are generally also hot, as the rays of heat are also reflected. The effect of glare on the eyes is obvious, and in the tropics this becomes a very important point. If a spot bare of vegetation, and with a white surface, must be used for habitations, some good result might be obtained by coloring the houses pale blue or green.

Chemical Composition of the Solid Parts of Soil.

Vegetable Matters.—Almost all soils contain vegetable matter. It exists in three chief forms—deposits, vegetable *débris*, and incrustations. Deposits occur in tracts of land which have been covered by silt brought down by floods, or which have been submerged by subsidence; forests have been thus buried, and again elevated. In the marshes of the Tuscan Maremma, and in many other cases, the vegetable forms can be traced without difficulty to a considerable depth, and the structure is even sometimes little changed, although so vast a period of time has elapsed. Vegetable *débris* produced by the decay of plants lies on, or is washed into, the soil, and in this way the ground may be penetrated to great depths. In some cases, especially in sandy plains at the foot of hills, the rain brings down very finely divided *débris*, and is filtered as it passes through the soil, so that each particle of sand becomes coated over or incrusted with a film of vegetable matter. If such a plain be subjected to alternate wettings and dryings, and to heat, the conditions of development of malaria may be present

in great intensity; although there is not only no marsh, but the sand is to all appearance dry and pure.

Animal matters.—The remains of animals are found in all but the oldest rocks; generally the animal constituents have disappeared, but it is remarkable how in some cases, even in geological formations as old as the tertiary strata, some animal matter may be found. On the surface there is perhaps no soil which does not contain some animal matters derived from dead animals or excreta, although, except in special cases, the amount is small. The soil of countries which have been long settled is, however, often highly impure in the neighborhood of habitations from the refuse (animal and vegetable) which is thrown out. In some loose soils cess-pits used for fifty years have never been emptied, and are still not full, owing to soakage.[1] Pettenkofer conjectures that in Munich 90 per cent. of the excretions pass into the ground. In clayey soil there is, of course, much less infiltration than in sandy, and often scarcely any. In India, the nitrification of vast tracts of land is for the most part owing to the oxidation of animal refuse.

A means of purification from animal impregnation has been, however, provided by oxidation, and the influence of growing vegetation. In all soils, except the hottest and driest, animal refuse, under the influence of minute fermenting organisms, passes into nitrates, nitrites, and ammonia and fatty hydrocarbons, rather rapidly, and these are eagerly absorbed by vegetation. A means is therefore pointed out which may keep the soil clear from dangerous animal impregnations, and this is no doubt one reason why improvement in public health follows improved cultivation. It has become quite clear that in the plans for the disposal of the human and animal excreta of towns, whether by wet or dry methods, an essential part of the plan is to submit these excreta to the influence of growing plants as soon as possible.

Mineral matters.—An immense number of mineral substances are scattered through the crust of the earth, but some few are in great preponderance, viz., compounds of silicon, aluminum, calcium, iron, carbon, chlorine, phosphorus, potassium, and sodium.

In examining the constituents of the soil round any dwellings, the immediate local conditions are of more importance than the extended geological generalizations; it is, so to speak, the house and not the regional geology which is of use. Still the general geological conditions, as influencing conformation and the movement of water and air through and over the country, are of great importance.

1. *The Granitic, Metamorphic, and Trap Rocks.*—Sites on these formations are usually healthy; the slope is great, water runs off readily; the air is comparatively dry; vegetation is not excessive; marshes and malaria are comparatively infrequent, and few impurities pass into the drinking water.

When these rocks have been weathered and disintegrated, they are supposed to be unhealthy. Such soil is absorbent of water; and the disintegrated granite of Hong-Kong is said to be rapidly permeated by a *fungus*;[2] but evidence as to the effect of disintegrated granite or trap is really wanting.

In Brazil[3] the syenite becomes coated with a dark substance, and looks like plumbago, and the Indians believe this gives rise to "calentura," or

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[1] Göttisheim in Basel (Das unterirdische Basel, 1868).
[2] Ost. Asiens, von C. Friedel, 1863.
[3] M'Williams on Yellow Fever in Brazil, p. 7.

fevers. The dark granitoid or metamorphic trap, or hornblendic rocks in Mysore, are also said to cause periodic fevers ; and iron hornblende especially was affirmed by Dr. Heyne of Madras to be dangerous in this respect. But the observations of Richter [1] on similar rocks in Saxony, and the fact that stations on the lower spurs of the Himalayas on such rocks are quite healthy, negative Heyne's opinion.

2. *The Clay Slate.*—These rocks precisely resemble the granite and granitoid formations in their effect on health. They have usually much slope ; are very impermeable ; vegetation is scanty ; and nothing is added to air or to drinking-water.

They are consequently healthy. Water, however, is often scarce ; and, as in the granite districts, there are swollen brooks during rain, and dry watercourses at other times swelling rapidly after rains.

3. *The Limestone and Magnesian Limestone Rocks.*—These so far resemble the former, that there is a good deal of slope, and rapid passing off of water. Marshes, however, are more common, and may exist at great heights. In that case the marsh is probably fed with water from some of the large cavities, which, in the course of ages, become hollowed out in the limestone rocks by the carbonic acid of the rain, and form reservoirs of water.

The drinking-water is hard, sparkling, and clear. Of the various kinds of limestone, the hard oolite is the best, and magnesian is the worst; and it is desirable not to put stations on magnesian limestone if it can be avoided.

4. *The Chalk.*—The chalk, when unmixed with clay and permeable, forms a very healthy soil. The air is pure, and the water, though charged with calcium carbonate, is clear, sparkling, and pleasant. Goitre is not nearly so common, nor apparently calculus, as in the limestone districts.

If the chalk be marly, it becomes impermeable, and is then often damp and cold. The lower parts of the chalk, which are underlaid by gault clay, and which also receive the drainage of the parts above, are often very malarious ; and in America, some of the most marshy districts are on the chalk.

5. *The Sandstones.*—The permeable sandstones are very healthy ; both soil and air are dry ; the drinking-water is, however, sometimes impure. If the sand be mixed with much clay, or if clay underlies a shallow sand-rock, the site is sometimes damp.

The hard millstone grit formations are very healthy, and their conditions resemble those of granite.

6. *Gravels* of any depth are always healthy, except when they are much below the general surface, and water rises through them. Gravel hillocks are the healthiest of all sites, and the water, which often flows out in springs near the base, being held up by underlying clay, is very pure.

7. *Sands.*—There are both healthy and unhealthy sands. The healthy are the pure sands, which contain no organic matter, and are of considerable depth. The air is pure, and so is often the drinking-water. Sometimes the drinking-water contains enough iron to become hard, and even chalybeate. The unhealthy sands are those which, like the subsoil of the Landes, in Southwest France, are composed of siliceous particles (and some iron), held together by a vegetable sediment.

In other cases sand is unhealthy, from underlying clay or laterite near the surface, or from being so placed that water rises through its permeable

[1] Schmidt's Jahrbuch, 1864, No. 5, p. 240.

soil from higher levels. Water may then be found within 3 or 4 feet of the surface; and in this case the sand is unhealthy, and often malarious. Impurities are retained in it, and effluvia traverse it.

In a third class of cases, the sands are unhealthy because they contain soluble mineral matter. Many sands (as, for example, in the Punjab) contain much magnesium carbonate and lime salts, as well as salts of the alkalies. The drinking-water may thus contain large quantities of sodium chloride, sodium carbonate, and even lime and magnesian salts and iron. Without examination of the water, it is impossible to detect these points.

8. *Clay, Dense Marls, and Alluvial Soils generally.*—These are always to be regarded with suspicion. Water neither runs off nor runs through; the air is moist; marshes are common; the composition of the water varies, but it is often impure with lime and soda salts. In alluvial soils there are often alternations of thin strata of sand, and sandy impermeable clay; much vegetable matter is often mixed with this, and air and water are both impure. Vast tracts of ground in Bengal and in the other parts of India, along the course of the great rivers (the Ganges, Brahmaputra, Indus, Nerbudda, Krishna, etc.), are made up of soils of this description, and some of the most important stations even up country, such as Cawnpore, are placed on such sites.

The deltas of great rivers present these alluvial characters in the highest degree, and should not be chosen for sites. If they must be taken, only the most thorough drainage can make them healthy. It is astonishing, however, what good can be effected by the drainage of even a small area, quite insufficient to affect the general atmosphere of the place; this shows that it is the local dampness and the effluvia which are the most hurtful.

9. *Cultivated Soils.*—Well-cultivated soils are often healthy, nor at present has it been proved that the use of manure is hurtful. Irrigated lands, and especially rice fields, which not only give a great surface for evaporation, but also send up organic matter into the air, are hurtful. In Northern Italy, where there is a very perfect system of irrigation, the rice grounds are ordered to be kept 14 kilometres (=8.7 miles) from the chief cities, 9 kilometres (=5.6 miles) from the lesser cities and the forts, and 1 kilometre (=1,094 yards) from the small towns. In the rice countries of India this point should not be overlooked.

10. *Made Soils.*—The inequalities of ground which is to be built upon are filled up with whatever happens to be available. Very often the refuse of a town, the cinders, or dust-heaps, after being raked over, and any salable part being removed, are used for this purpose. In other cases, chemical or factory refuse of some kind is employed. The soil under a house is thus often extremely impure. It appears, however,[1] that the organic matters in soil gradually disappear by oxidation and removal by rain, and thus a soil in time purifies itself. The length of time in which this occurs will necessarily depend on the amount of impurity, the freedom of access of air, and the ease with which water passes through the soil. In the soil at Liverpool, made from cinder refuse, vegetable matters disappeared in about three years; textile fabrics were, however, much more permanent; wood and straw, and cloth, were rotten and partially decayed in three years, but had not entirely disappeared. In any made soil, it should be a condition that the transit of water through its outlet from the soil shall be unimpeded. The practice of filling up inequalities is certainly, in many cases, very objectionable, and should only be done under strict supervision.

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[1] See Report on the Health of Liverpool, by Dr. Burdon Sanderson, and the late Dr. Parkes, p. 9 et seq.

SUB-SECTION III.

Malarious Soils.—Doubts have been expressed whether those paroxysmal fevers, which are curable by quinine, are produced either by telluric effluvia, or by substances passing from the soil into the drinking-water. The evidence, however, appears conclusive in favor of both these modes of entrance into the body.

If it be asked, What exact chemical conditions of soil favor the production of the malaria which causes periodical fevers ? the answer cannot be given, because no great chemist has ever systematically prosecuted this inquiry, and, in fact, it may be said that, singularly enough, there are few good analyses of malarious soils, although no problem is perhaps more important to the human race. It seems pretty clear that the mineral constituents of the soil are of little or no consequence. Malaria will prevail on chalk, limestone, sand, and even, under special conditions, on granite soils.

The following soils have been known to cause the evolution of the agent causing periodical fevers in the malarious zone :—

1. *Marshes.*—Except these with peaty soils, those which are regularly overflowed by the sea (and not occasionally inundated), and the marshes in the southern hemisphere (Australia, New Zealand, New Caledonia), and some American marshes, which, from some as yet unknown condition, do not produce malaria.

The chemical characters of well-marked marshes are a large percentage of water, but no flooding ; a large amount of organic matter (10 to 45 per cent.) with variable mineral constituents ; silicates of aluminum ; calcium, magnesium, and alkaline sulphates ; calcium carbonate, etc. The surface is flat, with a slight drainage ; vegetation is generally abundant.

The analyses of the worst malarious marshes show a large amount of vegetable organic matter. A marsh in Trinidad gave 35 per cent. ; the middle layer in the Tuscan Maremma, 30 per cent. The organic matter is made up of humic, ulmic, crenic, and apocrenic acids—all substances which require renewed investigation at the hands of chemists. Vegetable matter embedded in the soil decomposes very slowly ; in the Tuscan Maremma, which must have existed many centuries, if not thousands of years, many of the plants are still undestroyed. The slow decomposition is much aided by heat, which makes the soil alkaline from ammonia (Angus Smith), and retarded by cold, which makes the ground acid, especially in the case of peaty soils.

It would now seem tolerably certain that the growing vegetation covering marshes has nothing to do with the development of malaria.

2. *Alluvial Soils.*—Many alluvial soils, especially, as lately pointed out by Wenzel,[1] those most recently formed, give out malaria, although they are not marshy. It is to be presumed that the newest alluvium contains more organic matters and salts than the older formations. Many alluvial soils have a flat surface, a bad outfall, and are in the vicinity of streams which may cause great variations in the level of the ground water. Mud banks also, on the side of large streams, especially if only occasionally covered with water, may be highly malarious ; and this is the case also with deltas and old estuaries.

3. The soils of *Tropical Valleys, Ravines* and *Nullahs.*—In many cases large quantities of vegetable matter collect in valleys, and if there is any narrowing at the outlet of the valley, the overflow of the rains may be im-

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[1] Quoted by Hirsch, Jahresb. für die Ges. Med., 1870, Band ii., p. 209.

peded. Such valleys are often very malarious, and the air may drift up to the height of several hundred feet.

4. *Sandy plains*, especially when situated at the *foot of tropical hills*, and covered with vegetation, as in the case of the "Terai" at the base of some parts of the Himalayan range. In other cases, the sandy plains are at a distance from hills, and are apparently dry, and not much subjected to the influence of variations in the ground water. The analysis of such sand has not yet been properly made, but two conditions seem of importance. Some sands, which to the eye appear quite free from organic admixture, contain much organic matter. Fauré has pointed out that the sandy soil of the Landes in Southwest France contains a large amount of organic matter, which is slowly decomposing, and passes into both air and water, causing periodical fevers. This may reasonably be conjectured to be the case with other malarious sands. Then, under some sands, a few feet from the surface, there is clay, and the sand is moist from evaporation. Under a great heat a small quantity of organic matter may thus be kept in a state of change. This is especially the case along the dried beds of water-courses and torrents; there is always a subterranean stream, and the soil is impregnated with vegetable matter. In other cases the sands may be only malarious during rains when the upper stratum is moist.

5. Certain *hard rocks* (*granitic* and *metamorphic*) have been already noticed (p. 359), especially when weathered, to have the reputation of being malarious; more evidence is required on this point. As Friedel justly remarks of Hong-Kong, it is not the disintegrated granite, *per se*, which causes the fever, but the soil of the woods and dells, and the clefts in the rocks, which were derived from the granite, and are soon filled with a cryptogamic vegetation.

The *magnesian limestone* rocks which have been subjected to volcanic action have also been supposed to be especially malarious (Kirk, who instances the rocks at Sukkar), but the evidence has not been yet corroborated.

6. *Iron Soils.*—Sir Ranald Martin has directed attention to the fact that many reputed malarious soils contain a large proportion of iron. No good evidence has been adduced that this is connected with malaria, but the point requires further examination. The red soil from Sierra Leone, which contains more than 30 per cent. of oxides of iron, shows nothing which appears likely to cause malaria.[1] The peroxide of iron is a strong oxidizing agent, readily yielding oxygen to any oxidizable substance, and regaining oxygen from the air. It may, therefore, assist in the oxidation of vegetable matter in an iron soil.[2]

7. In certain cases, attacks of paroxysmal fever have arisen from quite *localized* conditions unconnected with soil, which seem, however, to give some clue to the nature of the process which may go on in malarious ground.

Friedel[3] mentions that in the Marine Hospital at Swinemünde, near Stettin, a large day-ward was used for convalescents. As soon as any man

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[1] Analysis of the Red Earth of Sierra Leone, by Assistant-Surgeon J. A. B. Horton, M.D., Army Medical Reports, vol. viii., p. 333.

[2] The surface soil of the Gold Coast (Connor's Hill, Cape Coast Castle), has also been analyzed by Mr. J. H. Warden, F.C.S. (Indian Medical Service). It contained only 3.28 per cent. of ferric oxide, and a trace of ferrous oxide; the organic matter was only 4.4 per cent. The surface soil is only eight inches thick, and below this is a stratum of a dark red color, like burnt bricks, probably containing more iron. The sample above-mentioned was brought home by Surgeon-Major J. Fleming, A.M.D.—Army Medical Reports, vol. xiv., p. 264.

[3] Ost. Asiens, p. 338. Berlin, 1863.

had been in this ward for two or three days, he got a bad attack of tertian ague. In no other ward did this occur, and the origin of the fever was a mystery, until, on close inspection, a large rain-cask full of rotten leaves and brushwood was found; this had overflowed, and formed a stagnant marsh of 4 to 6 square feet close to the doors and windows of the room, which, on account of the hot weather, were kept open at night. The nature of the effluvium was not determined.

Dr. Holden[1] relates an instance in which, on board a ship at sea, eight cases of ague occurred from the emanations of a large quantity of mould which had formed in some closed store-rooms, which were exposed to the bilge-water.[2]

SECTION II.

EXAMINATION OF SOIL.

Mechanical Condition of Soil.—The degree of density, friability, and penetration by water should be determined both in the surface and subsoil. Deep holes, 6 to 12 feet, should be dug, and water poured on portions of the soil. Holes should be dug after rain, and the depth to which the rain has penetrated observed. In this way the amount of dryness, the water-level, and the permeability can be easily ascertained.

The surface or subsoil can also be mechanically analyzed by taking a weighed quantity (100 grammes), drying it, and then picking out all the large stones and weighing them, passing through a sieve the fine particles, and finally separating the finest particles from the coarser by mixing with water, allowing the denser particles to subside, and pouring off the finer suspended particles. The weight of the large stones, plus the weight of the stones in the sieve and of the dried coarser particles, deducted from the total weight, gives the amount of the finely divided substance, which is probably silicate of aluminum.

Temperature.—The temperature at a depth of 2 or 3 feet, at two to four o'clock in the afternoon, would be an important point to determine in the tropics, and also the temperature in early morning. At present such observations, though very easily taken, and obviously very instructive, are seldom, if ever, made, although a commencement in that direction has been made in the investigations of Messrs. Lewis and Cunningham at Calcutta.[3] It might also be useful to take a certain depth of soil, say 6 inches, and, placing a thermometer in it, determine the height of the thermometer on exposure to the sun's rays for a given time at a certain hour.

Chemical Examination.—The chemical constituents of soil are, of course, as numerous as the elements; more than 500 minerals have been actually named. But certain substances are very rare, and, for the physician, the chief constituents of soils are the following substances or combinations:—Silica, alumina, lime, iron, magnesia, chlorine, carbonic acid, phosphoric acid, nitric acid. A few simple tests are often very useful, if we are uncertain what kind of rock we have to deal with. Few persons could mistake granite, trap, gneiss, or rocks of that class; or clay-slate or crystalline limestone. But fine white sandstones, or freestone, or even fine millstone grit, might be confounded with lime rocks, or magnesian limestone. A

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[1] American Journal of the Med. Sciences, January, 1866.

[2] Staff-Surgeon P. Mansfield, R.N., recounts an outbreak of yellow remittent fever on board ship at Rio, coincident with the growth of an enormous quantity of gigantic fungus in the hold. It seems unlikely, however, that this was more than a coincidence.

[3] Op. cit.

few drops of hydrochloric acid will often settle the question, as it causes effervescence in the calcium carbonate and magnesian rocks.[1]

A more complete examination should include the following points:

1. *Percentage of Water.*—Take 10 grammes of a fair sample of soil, and dry at a heat of 220°; weigh again; the difference is water or volatile substance.

2. *Percentage of Volatile Matters (including Water) destroyed by Incinera-*

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[1] It may be useful to give (from Page's Handbook of Geological Terms) a few compositions, and to define a few of the common mineralogical words used in geology.

Quartz.—Crystallized silica.

Felspar.—Silica, alumina (aluminum trisilicate), potash, or soda, and a little lime, magnesia, and ferric oxide, crystallized or amorphous.

Mica.—Silica, alumina, ferric oxide and potash, or magnesia, or lime, or lithia.

Chlorite.—Mica, but with less silica and more magnesia and iron.

Granite.—Composed of quartz, felspar, and mica.

Syenite.—Hornblende instead of mica.

Syenitic granite.—Quartz, felspar, mica, and hornblende.

Gneiss.—Same elements as granite, but the crystals of quartz and felspar are broken and indistinct.

Hornblende.—A mineral entering largely into granite and trappean rocks, composed of silica (47 to 60), magnesia (14 to 28), lime (7 to 14), with a little alumina, fluorine, and ferrous oxide.

Augite.—Like hornblende, only less silica (does not resist acids).

Hypersthene.—Like augite, only with very little lime; it contains silica, magnesia, and iron; resists acids.

Greenstone.—Hard granular crystalline varieties of trap, felspar, and hornblende, or felspar and augite.

Basalt.—Augite and felspar, olivine, iron pyrites, etc.

Trap.—Tabular greenstone and basalt.

Schist.—A term applied to the rocks mentioned above, when they are foliated or split up into irregular plates.

Clay-Slate.—Argillaceous arenaceous rocks, with more or less marked cleavage.

Limestone.—All varieties of hard rocks, consisting chiefly of calcium carbonate.

Oolite.—Limestone made up of small rounded grains, compact or crystalline, like the roe of a fish.

Chalk.—Soft calcium carbonate.

Magnesian Limestone.—Any limestone containing 20 per cent. of a salt of magnesia, frequently not crystallized.

Dolomite.—Crystallized magnesian limestone.

Kunkar.—A term used in India to denote nodular masses of impure calcium carbonate.

Gypsum—Selenite.—Calcium sulphate.

Gravel.—Water-worn and rounded fragments of any rock, chiefly quartz; size, from a pea to a hen's egg.

Sand.—Same, only particles less than a pea.

Sandstone.—Consolidated sand; the particles held together often by lime, clay, and ferric oxide.

Freestone.—Any rock which can be cut readily by the builder; usually applied to sandstone.

Millstone grit.—Hard, gritty sandstone of the carboniferous series, used for millstones. Grit is the term generally used when the particles are larger and sharper than in ordinary sandstone.

Clay.—Aluminum silicate.

Greensand.—Lower portion of the chalk system in England; sand colored by chloritous iron silicate.

Marl.—Lime and clay.

Laterite.—A term much used in India to denote a more or less clayey stratum which underlies much of the sand in Bengal, some parts of Burmah, Bombay presidency, etc.

Conglomerate.—Rocks composed of consolidated gravels (*i.e.*, the fragments water-worn and rounded).

Breccia.—Rocks composed of *angular* (not water-worn) fragments (volcanic breccia, osseous breccia, calcareous breccia).

Shale.—A term applied to all clayey or sandy formations with lamination; it is often consolidated and hardened mud.

tion.—Take another weighed portion of soil and incinerate at a full red heat; recarbonate with carbonic acid solution, or with ammonium carbonate; heat to expel excess of ammonia; dry and weigh.

3. *Absorption of Water.*—Place the dried soil in a still atmosphere, on a plate in a thin layer, and reweigh in twenty-four hours; the increase is the absorbed water. An equal portion of pure sand should be treated in the same way as a standard. It would be well to note the humidity of the air at the time.

4. *Power of holding Water.*—Thoroughly wet 100 grammes, drain off water as far as possible, and weigh; the experiment is, however, not precise.

5. *Substances taken up by Water.*—This is important, as indicating whether drinking-water is likely to become contaminated. Rub thoroughly 10 grammes in pure cold water, filter and test for organic matter by chloride of gold, or by evaporation and careful incineration; test also for chlorine, sulphuric acid, lime, alumina, iron, nitric acid.

6. *Substances taken up by Hydrochloric Acid.*—While water takes up alkaline chlorides and sulphates, nitrates, etc., the greater part of the lime, magnesia, and alumina are left undissolved. The quantity can be best determined by solution in pure hydrochloric acid.

(*a*) To 40 grammes of the soil add 30 C.C. of pure hydrochloric acid, and heat; note effervescence. Add about 100 C.C. of water. Digest for twelve hours. Dry and weigh the undissolved portion.

(*b*) To the acid solution add ammonia. Alumina and oxide of iron are thrown down. Dry and weigh precipitate.

(*c*) To the solution filtered from (*b*) add ammonium oxalate. Dry; wash and burn the calcium oxalate. Weigh as carbonate.

(*d*) To the solution filtered from (*c*) add sodium phosphate. Collect; dry and weigh (100 parts of the precipitate = 79 parts of magnesiuml carbonate); or determine as pyrophosphate.

The portion insoluble in hydrochloric acid consists of quartz, clay, and silicates of aluminum, iron, calcium, and magnesium. If it is wished to examine it further, it should be fused with three times its weight of sodium carbonate, then heated with dilute hydrochloric acid. The residue is silica. The solution may contain iron, lime, magnesia, and alumina. Test as above.

7. *Iron.*—Iron can be determined by the potassium dichromate, or by the permanganate. As the latter solution is used for other purposes, it is convenient to employ it in this case.

Dissolve 10 grammes of the soil in pure hydrochloric acid free from iron by aid of heat.

Add a little pure zinc, and heat to convert ferric into ferrous salts. Pour off the solution from the zinc that is still undissolved, and determine iron by potassium permanganate; *i.e.*, heat to 140° and then drop in the solution of permanganate till a permanent but slightly pink color is given. 1 C.C. = 0.7 milligramme of pure iron.[1]

Microscopic Examination.—Attention must now be paid to this, although it has not hitherto been much studied. *Bacteria* of various kinds have been found, and they have been observed to be more numerous in the most impure and unhealthy soils, as might have been anticipated. Some forms, however, are beneficial, as it is under their influence that the oxidation (nitrification) of nitrogenous organic matter is carried on. Either samples of th soil itself may be examined, or the air may be drawn out of the soil at different depths by means of an aspirator.

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[1] See Appendix A, Vol. II.

SECTION III.

METHOD OF EXAMINING A LOCALITY FOR MILITARY PURPOSES.

A place should be seen at all times of the year, in the wet as well as in the dry seasons, in the autumn and winter as well as in the spring, and at night as well as by day. The following order will be found a convenient one :—

1. *Conformation.*—Height above sea-level and elevation of hills above the plain. (Determine by mercurial barometer or aneroid, or, if possible, get the heights from an engineer.) Angle of declivity of hills ; amount of hill and plain ; number, course, and characters of valleys and ravines in hills ; dip of strata ; geological formation ; watersheds and courses ; exposure to winds ; situation, amount and character of winds ; sunlight, amount and duration ; rain, amount and frequency ; dust.

2. *Composition.*—Mineralogical characters. Presence of animal or vegetable substances ; amount and characters.

3. *Covering of soil* by trees, brushwood, grass, etc.

4. *Points for special Examination.*—Amount of air ; of moisture. Height of subsoil water, at the wettest and driest seasons. Changes in level, and rapidity of change of subsoil or ground water. Condition of vegetable constituents ; examination of substances taken up by water, etc.

Such a complete examination demands time and apparatus, but it is quite necessary.

A fair opinion can then be formed ; but if a large permanent station is to be erected, it is always desirable to recommend that a temporary station should be put up for a year, and an intelligent officer should be selected to observe the effect on health, to take meteorological observations, and to examine the water at different times of the year. Sometimes a spot more eligible than that originally chosen may be found within a short distance, and the officer should be instructed to keep this point in view.

The medical officer has nothing to do with military considerations or questions of supply, but if he is able to suggest anything for the information of the authorities, he should of course do so.

The opinion of Lind, whose large experience probably surpassed that of his contemporaries, and of our own time, should be remembered :— "The most healthy countries in the world contain spots of ground where strangers are subject to sickness. There is hardly to be found any large extent of continent, or even any island, that does not contain some places where Europeans may enjoy an uninterrupted state of health during all seasons of the year." [1]

In choosing a site for a temporary camp, so elaborate an examination is not possible. But as far as possible the same rules should be attended to. There is, however, one difference—in a permanent station water can be brought from some distance ; in a temporary station the water supply must be near at hand, and something must be given up for this.[2] The banks of rivers, if not marshy, may be chosen, care being taken to assign proper spots for watering, washing, etc. A river with marshy banks must never be chosen in any climate, except for the most imperative military reasons ; it is better to have the extra labor of carrying water from

[1] Lind, Diseases of Europeans in Hot Climates. 4th edition. p. 200.

[2] See remarks on this point, in the Regulations and Instructions for Encampments, p. 2.

a distance. A site under trees is good in hot countries, but brushwood must be avoided.

SECTION IV.

PREPARATION OF SITE FOR MILITARY PURPOSES.

In any locality intended to be permanently used, the ground should be drained with pipe drains. Even in the driest of the loose soils this is desirable, especially in hot climates, where the rainfall is heavy. In impermeable rocky districts it is less necessary. The size, depth, and distance of the drains will be for the engineer to determine ; but generally deep drains (4 to 8 feet in depth, and 12 to 18 feet apart) are the best. If there is no good fall, it has been proposed to drain into deep pits ; but usually an engineer will get a fall without such an expedient. A good outfall, however, should be a point always looked to in choosing a station. These drains are intended to carry off subsoil water, and not surface water. This latter should be provided for by shallow drains along the natural outfalls and valleys. As far as drainage is concerned, we have then to provide for mere surface water, and for the water which passes below the surface into the soil and subsoil.

Brushwood should usually be cleared away, but trees left until time is given for consideration. In clearing away brushwood, the ground in the tropics should be disturbed as little as possible ; and if it can be done, all cleared spots should be soon sown with grass. Brushwood should not be removed from a marsh.

In erecting the buildings, the ground should be excavated as little as possible ; in the tropics especially hills should never be cut away. The surface should be levelled, holes filled in, and those portions of the surface, on which rain can fall from buildings, well paved, with good side gutters. This is especially necessary in the tropics, where it is of importance to prevent the ground under buildings from becoming damp ; but the same principles apply everywhere.

In a temporary camp so much cannot be done ; but even here it is desirable to trench and drain as much as possible. It not unfrequently happens in war that a camp intended to stand for two or three days is kept up for two or three weeks, or even months. As soon as it is clear that the occupation is to be at all prolonged, the same plans should be adopted as in permanent stations.

The great point is to carry off water rapidly, and it is astonishing what a few well-planned surface drains will do.

The rules for improving the healthiness of a site may be thus summarized :—

1. Drain subsoil and lower the level of the ground water.
2. Pave under houses, so as to prevent the air from rising from the ground.
3. Pave or cover with short grass all ground near buildings in malarious districts.
4. Keep the soil from the penetration of impurities of all kinds by proper arrangements for carrying away rain, surface, and house water and house impurities.

END OF VOL. I.

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